SOVIET SPUTNIKS

"Soviet News" Booklet No. 25

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This booklet has been based on material published by Soviet scientists, among them

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Soviet News Booklet No. 25 London 1958

FIRST PRINTED JANUARY 1958
SECOND EDITION MARCH 1958

"The steel birds find the air increasingly crowded, and this has become possible in our country only at this time when our whole industrious nation, every working man and woman in our Soviet land have all together set out to turn mankind's dream of conquering the heights beyond the clouds into reality. . . .

"Today I am very certain that my other dream, interplanetary travel, which I have proved possible theoretically, will also come true.

"For forty years I have worked on jet-propelled engines and have thought that it would be several centuries yet before we could take a pleasure trip to Mars. But times are changing. I believe that many of you will witness the first flight beyond the atmosphere. . . ."

—From a speech by K. E. Tsiolkovsky recorded in 1933.

SOVIET SPUTNIKS

On October 4, 1957, a truly history-making event took place—the Soviet Union successfully launched Sputnik I, the first artificial Earth satellite. Less than a month later it was followed by Sputnik II, its younger but much bigger brother.

The launching of the first sputnik was a great triumph of man over nature. Man had surmounted the physical barriers which have kept him out of cosmic space; he had overcome the force of gravity and the resistance of the atmosphere.

However, there still remained the biological barrier. Could a living organism endure the conditions of space beyond the Earth's atmosphere?

The second sputnik furnished the answer to that question. This was the first step toward man's travel in cosmic space.

This booklet is based on material published in the Soviet press in connection with the launchings of the sputniks.

History is made

Our epoch has been rich in scientific and technological discoveries, some of them hard for us to assess properly at once.

Space flights and sputniks have long been discussed in detail in the scientific literature of many countries, and you would imagine that the importance of the question had long been appreciated. Now that almost every country has watched Soviet sputniks passing overhead, however, the history of the question needs re-examination.

A good opening question is: To what extent have the sputniks given man greater power over the forces of nature?

Cosmic Man

Most biologists today are inclined to the view that organic life, the highest manifestation of which is Man, has been bound to Mother Earth for more than 1,000 million years.

Now we are witnessing the fact that machines developed by Man have left the Earth and its atmosphere and have struck root in cosmic space, where nothing from the Earth had ever been seen before.

It will not be many years before we see flights to the Moon and the planets, not only by automatic space-ships without crews but also by vessels carrying people.

We are now standing on the border between two great epochs. The era in which Man has been confined to the Earth is coming to an end. The era of Cosmic Man is beginning.

No doubt this transformation will have little effect on Man's normal life for the next few years, or even decades. However, the prospects are unlimited.

In science and engineering we may talk of "tactical" and "strategical" achievements.

"Tactical" achievements rapidly become part and parcel of life. They bring us much that is useful but they do not change the nature of man's social existence.

"Strategic" achievements do not affect the individual directly. They make themselves felt slowly, but then they radically change all the relations of human society and its environment.

Planning Needed

The discovery of fire, the smelting of metals—these are past "strategic" achievements. But those human accomplishments were trifles compared with the conquest of cosmic space.

Only the discovery of nuclear energy—an achievement of our days —can in any way be compared with cosmic flight.

Together these two open up to humanity boundless vistas for further development.

Nuclear energy and cosmic flights can only be fully mastered when science, engineering and the economy are planned and managed in the interests of society as a whole.

It is, therefore, far from accidental that it was the Soviet Union which first succeeded in building and launching sputniks.

Rocketry has splendid traditions in Russia. Many valuable works on solid-fuel rockets were put out by Konstantinov, an artillery engineer of the last century.

In 1881 the Russian revolutionary Kibalchich suggested the idea of vertical flight by using a jet engine to overcome the force of gravity, while towards the end of the century Professor Meshchersky of St. Petersburg Polytechnical Institute developed the theory of bodies of

variable mass, a theory which still today is the basis for all calculations in rocket engineering.

Tsiolkovsky

However, the outstanding Russian contribution to early rocketry is the work of Tsiolkovsky.

Tsiolkovsky was the first to work out the principles underlying the theory of jet propulsion and the general theory of space flight.

This he did as early as 1903, and he put forward a concrete scheme for a multi-step cosmic rocket in 1929.

In the late twenties, groups of engineers were working on a number of concrete problems in the physics and technology of jet propulsion.

Tsiolkovsky was carrying on his research into rocket dynamics, which he had started at the beginning of the century.

By the twenties he had come to the conclusion that a single-stage rocket powered by chemical fuel would not be able to attain cosmic speed (five to seven miles a second).

In his search for greater speed, Tsiolkovsky conceived the idea of the multi-step rocket—an idea which has proved so fruitful.

Research into jet propulsion was given special state importance in the U.S.S.R. back in the early years of the Soviet republic.

This made it possible, early in the thirties—long before similar work had begun in other countries—to conduct bench tests of rocket engines in the U.S.S.R.

In 1933, a rocket designed and built by M. K. Tikhonravov, an engineer, for meteorological observations, was launched successfully.

Postwar Research

After the war, Soviet scientists began designing long-range guided rockets.

In 1947, systematic investigation of the upper layers of the atmosphere by rocket-lifted instruments, and study of the processes taking place beyond the atmosphere began.

It was discovered that the Sun radiates X-rays; information was obtained on the chemical composition of the atmosphere over sixty miles up; a study was made of the ionosphere, which plays a very important part in short-wave radio communication.

Observations were also being conducted of the condition of a living organism in the state of weightlessness, which occurs during the "free flight" of a rocket.

Many other valuable investigations have been carried out, widening the horizons of scientific knowledge and paving man's road into space.

The sputniks launched by the U.S.S.R. were part of the International Geophysical Year programme.

Scientific information provided by the sputniks is very broad, encompassing many aspects of the physics of the upper atmosphere and the study of outer space near the Earth.

Problems Studied

The state of the ionosphere and its chemical structure have been studied, and its pressure and density measured.

Magnetic measurements have been taken and the nature of the Sun's corpuscular radiation studied.

The primary composition and changes in cosmic rays, the ultraviolet and X-ray regions of the Sun's spectrum, the electrostatic fields of the upper atmosphere and microparticles have been investigated.

And, finally, a whole series of investigations have been made into the vital activity of the living organism in cosmic flight.

To obtain all this essential scientific material, the flight of the sputniks had to be systematically observed by means of astronomical (optical) instruments, by radio and radar aids.

> **Scientists all over the world have been observing the sputniks. They are serving, therefore, as a basis for the growth and enrichment of science throughout the world.**

They symbolise, therefore, not only the achievements of the Soviet Union but also the friendship and co-operation of all peoples—co-operation to give man greater power over the forces of nature, for the benefit of all mankind.

Launching Problems

WHY IS IT DIFFICULT to launch a sputnik? The first problem is the fact that the rocket has to be given a great speed. A single-stage rocket capable of going fast enough to "stay up" as a satellite—the "primary cosmic speed", roughly five miles a second—has to take along 150 to 200 times its own weight in fuel.

So far we have succeeded in building rockets in which the weight of fuel is 75-80 per cent of the total weight—in other words, only four times the weight of the unfuelled rocket itself.

But even so, even under these conditions, primary cosmic speed can only be attained by applying Tsiolkovsky's idea of a multi-step rocket, made up of two or three rockets, with their engines working in turn.

When the fuel of the first (rear) rocket has been used up, this stage falls away and the second starts working. And when the second has used up its fuel it in turn falls away, leaving the third rocket to take the sputnik into its orbit.

It took many years of hard work by big teams of engineers and scientists to put flesh on to Tsiolkovsky's daring ideas.

The greatest difficulties were encountered in designing the carrier rocket which was to place the satellite in its orbit.

This rocket had to be light and durable, but it had to have powerful (yet very light) engines which could operate under difficult heat conditions and would ensure a propelling force of hundreds of tons for a sufficiently long period.

An exceedingly precise and reliable system of control over the rocket's flight was also necessary.

And, finally, compact, light power sources had to be designed for radio transmitters, and remote-controlled equipment which could be relied upon to function for a considerable time under conditions of interplanetary flight.

Cosmic Rockets

Present-day super long-range rockets designed to fly at sub-cosmic speeds high above the Earth's surface, are set going by liquid-fueled engines.

In the main section of such an engine—the combustion chamber—special fuel burns continuously and the gases produced are ejected, developing the force of recoil, or what is called the engine's thrust.

Since, over most of its path, a rocket has to fly in extremely rarefied layers of the atmosphere, where the amount of oxygen is negligible, the oxygen it needs to burn its fuel has to be carried, too.

To develop the great thrust necessary, the rocket has to have several engines, for attaining a thrust of even a few score tons from one engine is a problem which has not yet been solved.

Even on the best present-day rockets, the structure weighs about 20 per cent of the combined weight of the rocket and fuel.

That is why the first thing that has to be done is to manage to attain the speed of cosmic flight with less fuel.

Tsiolkovsky showed that to accomplish this the speed at which the gases flow out of the engine must be increased as far as possible.

Then each pound of fuel will produce a more powerful "recoil", so less fuel will be required to obtain the necessary thrust.

How is that to be done? The answer—in words at any rate!—is easy. You take the fuel that gives the most heat and burn it in the combustion chamber under very high pressure.

Problems to Solve

In an engine working efficiently on such fuel, pressures of fifty atmospheres or more should be developed at a temperature of some 3,000°C.

Although such an engine functions for only a few minutes, no material at present available to engineering could stand the strain of work under such conditions.

This problem had never come up before, as the most powerful thermal engines of other types developed only from a hundredth to a thousandth part of the power developed by liquid-fueled rocket engines.

To build a reliably working engine, first the problem of cooling and of making its walls strong enough had to be solved.

And that is not so simple! Even with good cooling it is very difficult to keep the wall temperature down to less than 500-800°C.

The problem of cooling is a basic one but not the only one. To design the engine we have to know what laws operate in the mixing and burning of the fuel, how to ensure that it is fed uniformly to the engine, how to produce safely the initial ignition of the fuel and, finally, what loads the engine parts will be subjected to while it is in operation.

Special attention has to be given to ensure uniform feeding and combustion of the fuel, as otherwise strong vibrations will develop, destroying the engine.

This problem is just as difficult as the problem of cooling.

Joint Efforts

Solution of all these problems would be impossible without the joint efforts of scientists working in the field of gas dynamics, the theory of combustion, hydraulics and cybernetics.

Only on this basis have the engineers been able to design the engine for the carrier rocket.

Without the work done in ballistics, aerodynamics, gas dynamics and the theory of strength it would have been impossible to build the carrier rocket.

To ensure that the sputnik gets exactly into its orbit, the whole path of the rocket has to be calculated in advance.

Experts in ballistics and aerodynamics, especially the latter, had to do a great deal of work. The physical structure of the upper atmosphere differs sharply from the air we know. Since the air is so rarefied, the molecules of gas in it travel at tremendous speeds.

At an altitude approaching 200 miles, the rocket travelling at five miles a second comes up against a pressure of five milligrammes per square centimetre.

As they bombard the flying body the molecules impart their energy to it.

To make sure that the rocket or sputnik does not burn away during the launching or flight, highly complex computations have to be made to determine the air resistance it will encounter.

Utmost Precision

An efficient and precise system of automatic control is needed to look after the fuel feeding and the flight characteristics, to detach the used-up steps of the rocket, and to keep the rocket in its proper trajectory.

When the rocket reaches its top speed of 17,500 m.p.h.—twenty times the velocity of sound—an error of only about thirty miles an hour in the speed or half a degree in the direction of the rocket's motion can prove fatal.

A rocket is made up of tens of thousands of parts, each performing a certain task. If any one of them fails to work perfectly, the rocket may not fly and will not carry out the programme set for it.

Extreme care in manufacture and assembly of the rocket was necessary to ensure success.

In the few seconds that it takes the rocket to rise, a monstrous power is developed as the fuel burns, reaching several million kw.

The colossal speed of the outflow of gases from the engine—several times faster than the speed of a bullet—and the tremendous temperatures, require special fuels and special construction to make it possible to use such fuels.

The energy of the useful mass of Sputnik II, its kinetic force at a speed of five miles a second, is equal to the energy of a goods train weighing 300,000 tons travelling at about 25 m.p.h.

No such train could travel on railway tracks, though, for it would

need thousands of waggons, making the train scores of miles long.

Of course, you just can't travel at five miles a second on land! Such speed is possible only in outer space, where there is no resistance at all.

The Take-off

How is a sputnik launched?

. Towering over the concrete apron is the launching tower. Through the open-work structure of steel trusses the nose of the streamlined rocket points straight up into the sky.

Immediately before the launching, the steel framework of the tower is towed away along its special track.

Everyone takes shelter behind thick reinforced-concrete walls. The launching is made by remote control.

The rocket takes off vertically to an altitude of about a mile and a quarter. Then, guided by its programmed control device, it begins levelling off.

The first-step rocket engine stops, a minute or two after the start. By that time the rocket has attained a speed of something like 4,500 m.p.h. and is travelling at an angle of about 45° to the Earth's surface.

After the first step has fallen away, the second-step engine starts, bringing up the speed to 11,250-12,500 m.p.h.

From then on the rocket coasts along by inertia, tracing in space a gigantic ellipse, the summit of which touches the set orbit, hundreds of miles high, so that its path at that point is parallel to the Earth's surface.

By that time the rocket is more than 600 miles away from where it started.

Then comes the decisive moment. The rocket is at the set altitude but its speed is not enough to make it a sputnik.

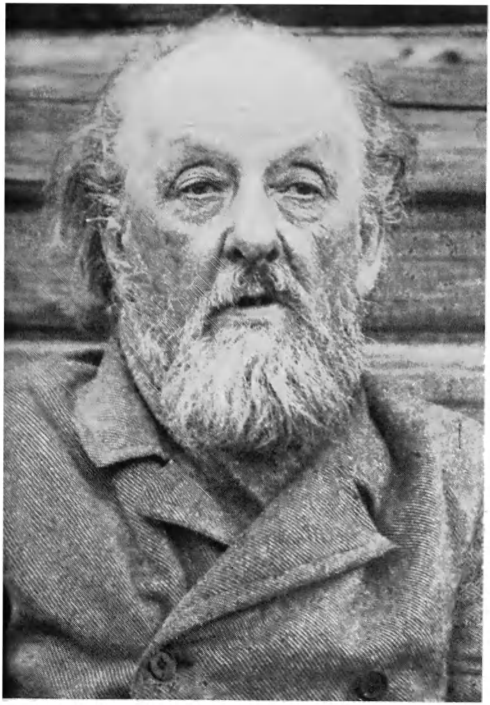
If the rocket does not get a further impetus, in a second it will start falling back on its course to the earth, along the second half of the ellipse.

But this will not happen, for the last-stage engine begins to work. Another effort and the rocket picks up the needed speed of something like five miles a second.

The rocket's engines are silent. A sputnik has been born. . . .

The Design

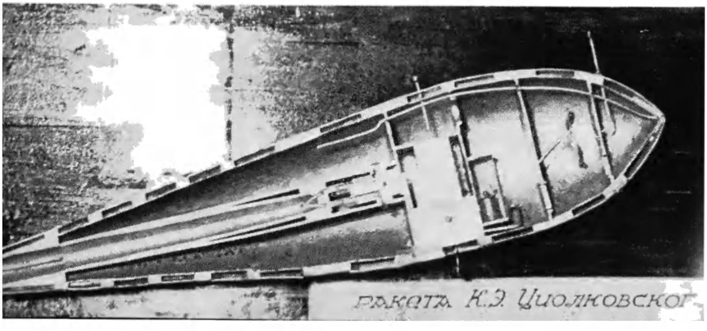
Sputnik I was spherical in shape. It was 22.8 inches in diameter and weighed 184.3 lb. Its hermetically sealed body was made of aluminium alloys, and its surface was polished and specially treated.

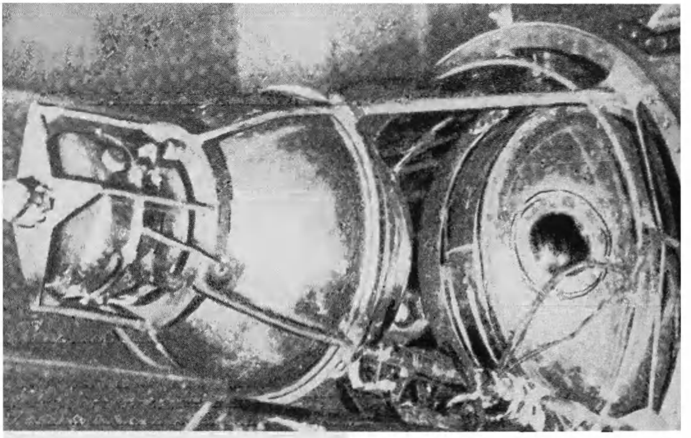


EARLY DAYS

One of the first to be interested in rockets and sputniks was the Russian schoolmaster Konstantin Tsiolkovsky (1857-1935) who became a pioneer in aeronautics, rocketry and inter-planetary communication research.

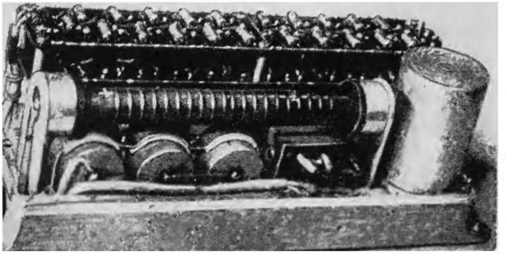
The model of a spaceship below, prototype of the modern rocket, was made by Tsiolkovsky over 50 years ago—in 1903.



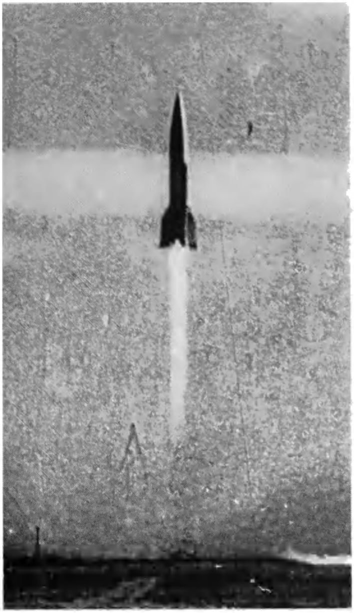


Nose of Sputnik II with cone removed. From left to right are the solar and cosmic ray instruments, radio and Laika's compartment.

The apparatus in Sputnik II for the study of solar radiation (see further diagram).

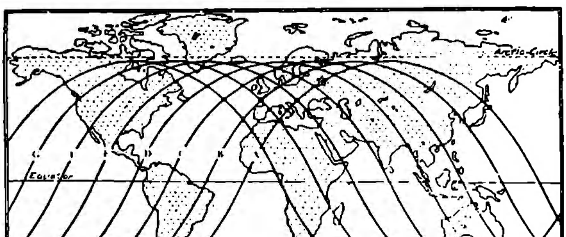


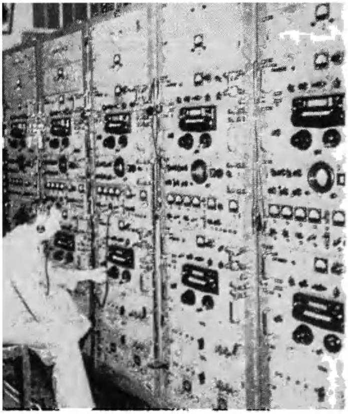
Sputnik II. Apparatus for study of cosmic rays (see further diagram).



A Soviet rocket leaves on its long journey. The top of the supporting derrick can just be seen above the cloud of gases.

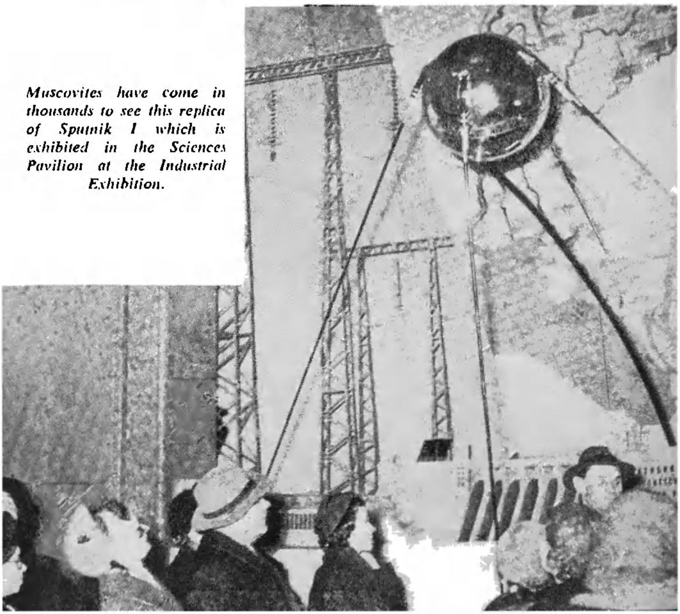
The approximate trajectory of Sputnik I during four consecutive revolutions (a, b, c, d) of the Earth. (Oct. 4th, 1957.)





Ivan Pryzhkov, engineer at one of Moscow's radio stations, is seen above checking the signals from Sputnik I.
On the right, these youngsters in Moscow's School No. 59, hear the "bleep, bleep" loud and clear on less elaborate equipment.

Muscovites have come in thousands to see this replica of Sputnik I which is exhibited in the Sciences Pavilion at the Industrial Exhibition.



All its apparatus and power sources were located inside the body. Before being launched it was filled with a gaseous nitrogen.

On the outside surface, aerials were attached—four rods 7 ft. 10 in. to 9 ft. 6 in. long.

While the sputnik was being taken out to its orbit, these aerials were folded back against the body of the rocket, but after the first two steps had fallen away the aerials turned out on their hinges, assuming the position shown in the famous photo.

While travelling in its orbit, the sputnik is subjected from time to time to sharply changing heat influences—heating by the Sun's rays while on the "day" side of the Earth and cooling when flying in the Earth's shadow.

Then there is the effect of the atmosphere's heat and so on. A certain amount of heat is generated, too, when the apparatus on the sputnik is working.

As far as heat is concerned the sputnik is an independent heavenly body, exchanging radiant heat with the surrounding space. To ensure for a considerable period the normal temperature needed for the functioning of the apparatus on the satellite was, therefore, a fundamentally new and difficult problem.

The needed temperature on Sputnik I was ensured by regulating the heat resistance between the envelope and the equipment, through the forced circulation of the nitrogen in the satellite.

Two radio transmitters were installed in the sputnik, constantly emitting signals on frequencies of 20.007 and 40.002 megacycles (15 and 7.5 metre wavelengths respectively).

Sputnik II

Sputnik II was the whole last stage of the rocket, in which all the scientific and measuring instruments were installed.

This arrangement materially simplified the problem of determining the satellite's co-ordinates, with the aid of optical instruments.

Our experience with Sputnik I showed that observations of the carrier rocket were simpler than of the satellite itself.

The carrier rocket was very much brighter than the sputnik.

The combined weight of the apparatus, of the dog and of the batteries on Sputnik II was almost exactly half a ton.

On a special frame in the forward part of the last stage of the rocket were installed an instrument for measuring solar radiations in the ultra-violet and X-ray regions of the spectrum, a spherical container with the radio transmitters and other apparatus, and the hermetically sealed chamber in which the dog was kept.

The instruments for studying the cosmic rays were mounted outside the body of the rocket.

A special cone protected all these instruments while the rocket was travelling into orbit. When it was in orbit, the cone was discarded.

The radio transmitters and their batteries, the system of heat regulation and the sensitive elements registering the changes in the temperature and other things were put into a spherical container which resembled Sputnik I in design.

The signals on 15 metres wavelength—the famous "bleep"—lasted an average of about three-tenths of a second, as did the pauses between them. But they changed within certain limits when there were changes in the temperature and pressure in the spherical container.

Amateurs Help

The transmitter on 7.5 metres gave out a continuous signal.

These broadcasts were audible regardless of the state of the ionosphere, enabling a great many radio amateurs in all parts of the world to co-operate in the observations.

> **Reports from these amateurs proved that signals from the sputniks could be reliably received by ordinary amateur receivers at ranges, in some cases, of nearly 10,000 miles.**

The dog was put in a hermetically sealed chamber with food and an air-conditioning plant, consisting of a regenerating outfit and a system of heat control, installed.

Also installed were instruments to register the dog's pulse, respiration and blood pressure, apparatus to take electrocardiograms, and sensitive elements to measure the temperature and pressure in the chamber.

The animal's chamber, like the container itself, was made of aluminium alloys, its surface polished and specially treated so as to absorb the right amount of solar radiation.

The heat regulation system installed maintained the temperature within fixed limits, through forced circulation of gas in the chamber.

The equipment also included telemetering apparatus for measuring the temperature, and batteries to provide power for the radio and the various scientific and measuring instruments. The temperature on the outside and inside surfaces of the dog's chamber was measured by means of special apparatus. Temperature gauges were also installed on individual instruments and parts of the sputnik. The radio-telemetering device ensured the transmission of all these

readings and those of the instruments installed in the sputnik, to the Earth at fixed intervals.

The full programme of investigations on Sputnik II was calculated to work for seven days. The radio transmitters then ceased functioning, and further observations were confined to radar and optical observations of its movements.

Sputniks' Orbits

MISSILES HAVE BEEN SHOT over long distances before, but no matter how fast they have travelled they have always hit the ground sooner or later.

But the sputniks were given a speed roughly ten times as fast as the speed of a shell as it leaves a long-range gun.

So their flight distance increased by a leap; they began revolving around our planet like little moons.

Indeed, if there had been no air resistance—which though it does not amount to much in the rarefied air is nevertheless appreciable—their movement would never have stopped.

These little moons, however, do not move from east to west, like all other heavenly bodies do.

Observers, depending on where they are, saw them flying north-east or south-west, and sometimes observers near the 65th parallel saw them flying eastwards.

The curve along which the sputniks moved was very intricate. They moved in orbits that were ellipses, with one of the focuses lying in the centre of the Earth.

From the Ground

The Earth rotates on its axis, so the sputniks at each succeeding revolution round the Earth naturally appeared over a different area.

Actually they shifted approximately $24\frac{1}{4}°$ in longitude each time.

As a result, at the latitudes of, say, London, each succeeding turn passes some 1,000 miles west of the preceding one; at the equator the shift is roughly 1,500 miles.

The plane of the sputniks' orbits was inclined at an angle of 65° to the plane of the Earth's equator.

Their path, therefore, crossed all the land areas lying approximately between the Arctic and Antarctic Circles.

Because of the Earth's rotation about its axis, the angle of slope of

the path to the equator differs from the angle of slope of the plane of the orbit.

On entering the northern hemisphere the path crosses the equator at an angle of 71.5 degrees in a north-easterly direction.

Then the path gradually turns more and more to the east and touching the parallel 65° North Latitude, turns to the south, crossing the equator at an angle of 59° to the south-east.

In the southern hemisphere the path touches the 65° parallel, after which it is deflected to the north and again enters the northern hemisphere.

Launching the sputnik on this orbit is a more difficult task than launching it on an orbit near to the plane of the equator. For if it is launched along the equator, the full speed of the Earth's rotation could be used to accelerate the speed of the rocket.

Some people have been puzzled by the apparent changes in the sputnik's direction.

An observer notes, for instance, that the little moon is travelling in a south-easterly direction. Then some time later it again appears over the same area but this time flying north-east.

Does this mean that the sputnik has changed to a different direction? No! The apparent change in direction is due to the fact that in the interval between the two observations, the spot on the Earth's surface has turned half a circle about its axis.

How to Find the Orbit

Sputnik I made approximately fifteen revolutions around the Earth in twenty-four hours in the initial stages of its flight.

Amateur trackers could easily check which path the sputnik was travelling along in the following manner. One requires a globe, to the arm of which one fastens a circle of wire encircling the globe at an inclination of 65° to the equator. Whenever a radio fix can be obtained the globe is spun so that the named point and the wire coincide. The wire then marks the sputnik's orbit, and a simple calculation would give the position of the sputnik at any particular time.

Let us assume that Radio Moscow announced that it had passed Moscow at a certain time. In one minute Sputnik I flew through 360° divided by 96.2 (the period of its revolution round the Earth in minutes). This gives us a shift of 3.74°, or roughly 45° in twelve minutes. This position should be marked on the wire. During this same period the Earth itself has turned on its axis three degrees to

the east, and the globe is turned accordingly. The mark on the wire then gives the sputnik's new position.

Similarly the reverse problem can be solved, of finding the place at a particular time, or the time at a particular place—or even whether it will pass over a given point at all.

If with this device we draw consecutive tracks of Sputnik I over the globe, as is done in a previous diagram, we shall see that every sixteenth track coincides almost exactly with the first, the seventeenth with the second, and so on.

Owing to the greater period of rotation, Sputnik II makes some fourteen complete turns round the Earth in twenty-four hours, whilst Sputnik I, in its initial period, made about fifteen turns. Due to the rotation of the Earth the shift of Sputnik II with each successive revolution is 1.15 times greater relative to Sputnik I, and the distance on the Earth's surface between the paths of the two sputniks grew to this extent.

Why West to East?

From what has been said it is clear that artificial satellites will never rise in the east or set in the west as we are accustomed to see the Sun do. Why?

Theoretically it is possible to launch a satellite to revolve, so to speak, in the general stream of heavenly bodies. Practically, however, this is not done because, rotating on its axis, the Earth can help in the launching if the sputnik takes off in the same direction—or it can hinder it if it is launched in the opposite direction.

However, to make full use of the speed of the Earth's rotation is not always a good idea.

In fact, if the satellite is launched in the direction of the Earth's motion, it will fly only over a narrow belt round the equator.

For Sputnik I, a compromise decision was adopted by which the Earth's daily rotation was used—but only to an insignificant degree. We wanted the sputnik to fly over as much of the world as possible to get the maximum amount of scientific information from its flight.

Evolving the Orbit

So far we have assumed that the sputnik moved along its orbit at a uniform speed. However, even where there is no air resistance, such a movement would be possible only if the orbit were a perfect circle, its centre coinciding with the Earth's centre.

Actually, however, each sputnik describes an ellipse, and for this

reason, when it passes through the perigee—the point on the orbit nearest to the centre of the Earth—its speed is appreciably greater than when at apogee—the point on the orbit farthest from the Earth.

The two sputniks moved in a very slightly flattened ellipse. The difference in length between their major and minor axes was less than a quarter of 1 per cent.

This is practically a circle, but the centre of this "circle" is a little off from the Earth's centre.

The period the sputnik took to circle the Earth gradually changed because of the resistance it encountered, and as the orbit contracted the time it took to circle the Earth also grew shorter.

The speed at which the period changed showed how fast the shape of the orbit was changing.

At first this was very slow. But gradually the orbit became more and more circular.

When the sputnik entered the denser layers of the atmosphere the braking force was quite substantial, and the satellite blazed away like a meteor.

Sputnik I vaporised in this way on January 4, after ninety-two days in the sky. It had travelled a total distance roughly equal to a journey from Earth to Mars.

Other conditions being equal, the greater the mass of a satellite the longer it will survive—since the greater the mass, the less speed it will lose in dropping through the upper layers of the atmosphere.

Why Must Sputniks Burn?

After take-off, the launching rocket rises straight up. This enables it to cross the lower, dense layers of the atmosphere in the shortest way.

The rocket's speed rises gradually. Passing through the dense lower layers of the air there is not enough time for it to become greatly overheated.

It therefore manages to get out to a greater altitude where the air is very much rarefied.

On returning to Earth, however, the movement of the rocket—or the sputnik—is very different.

> **Gradually descending, they enter the dense layers of the atmosphere at a tremendous speed and at a relatively small angle to the horizon.**

Spiralling towards the Earth they will travel great distances through these layers, and as the friction grows the bodies will rapidly grow very hot and "burn up".

Choosing an Orbit

The orbit of a sputnik absolutely must lie in a plane which passes through the centre of the Earth.

A satellite can be designed to revolve in the plane of any Great Circle, or in the plane of the equator, but its orbit will never stay in the plane of a parallel of latitude.

A sputnik launched on such an orbit will certainly shift to the plane of the equator or fall back to Earth.

A sputnik's path has to lie at a great height, beyond the dense atmosphere, otherwise the resistance of the air will act as a brake and the circular flight will turn into a spiral, ending in the satellite falling to earth.

Fortunately, it is not necessary to lift it too high.

Round about 125 miles above the Earth air resistance is almost negligible.

In selecting orbits for future satellites, specific features of some of them must be taken into account.

For instance, a characteristic feature of an orbit at an altitude of 346 miles is that the satellite's period of revolution along it will be exactly an hour and a half.

Travelling in it, the satellite will circle the Earth eighteen times in twenty-four hours.

Moving in a "two-hour" orbit, which lies at an altitude of 1,037 miles, it will circle twelve times.

Obviously there is also a "24-hour" orbit at about 22,500 miles.

Especially interesting is a 24-hour orbit in the plane of the equator. In such a case, the satellite, travelling at breakneck speed, appears to hover motionless over some point of the equator, as though on top of an invisible tower thousands of miles high.

There are many other no less interesting orbits.

Sputnik II's Orbit

Sputnik II was taken out to its orbit by means of a three-step rocket. While being taken out to the orbit, the rocket rose to an altitude of several hundred miles. By the time it reached orbit, its fuel had been used up.

Thereafter, the sputnik moved by kinetic energy gained by the rocket while speeding up into the orbit.

The speed imparted to the rocket's last stage was more than the speed needed for movement in the circular orbit at a constant altitude at which it entered its orbit.

Sputnik II did not therefore move in a circular orbit but in an elliptical one, its farthest point from the Earth being roughly 1,050 miles, or almost double the highest altitude attained in launching Sputnik I—560 miles.

The initial period of its rotation around the Earth was 103.7 minutes.

Forces Operating

The braking force operating against a satellite depends not only on the density of the atmosphere but also on the shape of the satellite and on the ratio of its weight to cross-section area.

The greater this ratio the smaller the loss in speed.

Two satellites taken out to the same orbit but moving against different braking forces will after a certain period move along different orbits, since their orbits will vary with time at a different rate.

And while the orbits are contracting it is mainly by decrease in the maximum height.

Sputnik I and its carrier rocket at first moved approximately in the

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SPUTNIKS ON STAMPS

The Soviet sputniks captured the popular imagination everywhere, and they appeared in every country as symbols of speed and progress, incorporated in stamps, cartoons, advertising, and after-dinner speeches. A new word had entered many languages.

Commemorative postage stamps were soon issued in the Soviet Union. Here we see the 40-kopeck and the 1 Rouble issues.

Left: The 40-kopeck issue showing Sputnik I in orbit.

Right: The symbolic figure speeds the satellite on its way, on the 1 Rouble stamp.

same orbit and their periods of revolution differed only slightly, being about 96.2 minutes for each.

Later, owing to the fact that Sputnik I experienced less resistance than the carrier rocket, their orbits began to differ materially.

When the trajectory measurements have been worked out, it will be possible to establish fully the whole process of evolution of the orbits and to obtain important information on the distribution of the density of the upper atmosphere.

Later on it will be possible to predict reliably how long sputniks will survive.

Why do they move?

MODERN CELESTIAL MECHANICS is based on the law of gravitation. The movement of the "little Moon" around the Earth is subject to the same laws as that of the real Moon, or the movement of the Earth and other planets of the solar system around the Sun.

Sputniks, we have seen, move around the Earth at great speed. If there had been no gravitation, they would have been moving in a vacuum uniformly and in a straight line, and would have speedily disappeared into outer space.

The attraction of the Earth, however, distorts their path, making them circle round it.

This force of attraction is of a definite magnitude, and that is why sputniks can make their circular movement around the Earth only at certain and quite definite speeds.

The Needed Speed

In order that a satellite moving around the Earth should continue at a constant altitude, it must every instant get as far away from the Earth as it gets nearer to it in its continuous falling.

In the first second, a body falling freely to the Earth loses approximately sixteen feet of altitude. Obviously in this second the satellite has to get away from the Earth the same sixteen feet, so that there is no change in the altitude at which it is moving.

This makes it possible to build a right-angled triangle and, making use of Pythagoras, to figure out the speed we want.

For a satellite moving not very far away from the Earth's surface, the speed, we have seen, is roughly five miles a second.

You ask: why is the speed the same for bodies of any weight, when the force of attraction acting on a heavier body is greater?

At first sight it would seem that such a body should orbit at greater speed, because of the action of force of attraction.

However, if we bear in mind that it is harder to deflect a heavier body from movement in a straight line, and exactly as many times more as it weighs more, it will become clear that the speed of a satellite's movement does not depend on its weight.

The speed of movement of Sputnik I in its orbit, therefore, will be approximately the same for other and heavier satellites put into the same orbit.

Heavier satellites do, however, present a number of other obstacles. Their launching, therefore, will be a new and important stage in the development of science and engineering.

Altitude and Speed

The required speed of a sputnik changes with altitude. The force of the Earth's attraction diminishes as the distance from the Earth increases, and therefore in a higher orbit a satellite must move at a lower speed.

For satellites moving in different orbits lying about 600 miles above the Earth's surface, the difference in the speed of motion is comparatively small.

However, for satellites moving at considerably greater distances from the Earth the speed becomes substantially less.

For instance, the Moon, which is also a satellite of the Earth and is about 240,000 miles away, moves round the Earth at a little more than half a mile a second—that is, a speed roughly one-eighth that of a satellite flying close to the Earth.

In order to launch an artificial Earth satellite it has to be lifted to a great height and accelerated to the speed required for its movement in the orbit at that height.

No energy is expended as the satellite moves in its orbit.

Because in a higher orbit the satellite moves at lower speed, it follows that when the satellite is taken out to such an orbit it needs to be accelerated to a lower speed.

This, however, does not mean that it is easier to launch a satellite on a higher orbit than on a lower one, for the difficulties in lifting it to great altitudes are very great and the higher it goes the greater the difficulties.

Primary Cosmic Speed

We pointed out before that at every height the movement of a satellite in a circular orbit has to proceed at a definite speed.

If the speed is less than the one required, the Earth's attraction will deflect it more easily from a straight line; the path will be distorted in the direction of the Earth and the satellite will begin to drop.

If the speed is only slightly less than required, the drop will be relatively small, and the satellite, after drawing closer to the Earth and gaining a certain speed thereby, will be able once again to rise to the earlier height, repeating the drop and rise periodically on each revolution.

If the difference in the speed of movement from the circular is somewhat greater, the drop may prove precipitate.

If the speed of the satellite is too much it will be harder for the force of gravity to deflect its course closer to the Earth's surface and the satellite will then be able to rise to a very great height, much higher than to which it was originally lifted by the rocket.

Should the speed reach something like seven miles a second, the satellite will disappear into interplanetary space.

The speed of five miles a second is called the primary cosmic speed. It is the speed a satellite must attain to move in an orbit close to the Earth.

A speed of seven miles a second is called secondary cosmic speed, and an interplanetary vessel launched near the Earth must have it to overcome the Earth's attraction and to begin to move in interplanetary space.

Speeds between the primary and secondary cosmic speeds will make it possible to launch a satellite moving in long elliptical orbits. The greater the initial speed, the farther away from the Earth the orbit will extend.

With present progress in the building of rockets it is quite realistic to speak of launching a sputnik which can survive for thousands of years.

Watching Sputniks

A VERY IMPORTANT ELEMENT of satellite research is the observation and recording of their motion, treatment of the records and forecast of their further motion on this basis.

During the first period of the sputniks' motion the scientific stations conducted observations with the aid of radar and radio direction finders and by means of optical instruments and photography.

After the radio transmitters stopped working, the observations were conducted mainly by the last two methods.

All data obtained by the stations and the observations of amateurs are analysed by electronic computing machines.

How valuable these results will be, depends on how correct and precise was the data obtained in observing the sputniks as they moved in their path.

For example, to determine the Earth's exact shape for geodetic purposes, the orbit of the satellites' motion has to be determined accurately within a few seconds of the arc and a few milliseconds in time.

Many of the ground stations measuring the position of the sputnik in its path transmitted the results of their observations to a central station, where the orbit was determined.

The more observations made, the more accurate the determination of the orbit.

Radio amateurs have been very helpful in the collection of radio observations; in particular, thousands of Soviet radio amateurs have conducted observations of the sputniks, using ordinary radio sets as well as receivers designed specially for the purpose.

Diagrams of such receivers and of their direction finders were published in *Radio*, a Soviet popular-science magazine, long before the first sputnik was launched.

Preliminary reports of Soviet results obtained from observations of the sputniks were circulated to foreign scientists, co-operating in the International Geophysical Year programme, in January.

The Actual Path

Optical observations in conjunction with radio have made it possible to ascertain the actual paths of the sputniks much more exactly, and to make geographical calculations much more precise.

Observations of the sputniks with the aid of astronomical instruments present certain difficulties.

They are not similar to observations of ordinary heavenly bodies, for the sputniks move very quickly across the sky, at an average speed of about one degree per second.

To make sure that the observations are reliable, each optical station has one or two sets of optical instruments placed as a barrier on the meridian and along the vertical circle perpendicular to the apparent orbit of the sputnik.

In addition, the method employed in searching for the sputnik is based on the so-called "local-time rule".

This method turns to account the fact that the sputnik's orbit is not involved in the rotation of the Earth, and the sputnik itself passes

through a given latitude in local sidereal time, which changes slowly as the orbit revolves in absolute space around the Earth's axis, owing to the divergence of the gravitational field from the centre.

Therefore, with respect to a particular station, the satellite in the course of its motion passes successively through the points in the celestial sphere which may be called waiting points.

If the axis of the optical instrument is regulated so as to be directed to the waiting point next in order in the celestial sphere as figured out in advance, then sooner or later the satellite will inevitably be detected, and when detected the time of its passage is noted with the aid of a chronometer or by radio time signals.

In this way the accuracy in determining the time the satellite passes through their range of vision will not be above a second.

Among other things, Soviet amateur astronomers at sixty-six optical observation stations and all observatories have at their disposal many special improved wide-angle optical instruments.

The observation stations also have sets of equipment making it possible to fix the sputniks in the celestial sphere with the accuracy of one degree in position, and one second in time.

Taking Photographs

The satellite can be followed up by instruments with a focal distance of 60 to 100 centimetres. In such an instrument, as the satellite passes through its range of vision, the rate of movement of its image is up to about an inch a second.

A particularly important part is played by optical observations of the satellites at the last moment of the final stage of their passage, when they make the last spiral movements before entering the atmosphere's denser layers and when they begin to burn up.

The photographs taken by observatories in the Soviet Union and other countries made it possible to define the orbits of the sputniks and of the carrier rocket with considerably higher precision.

Exact pictures of the position of the sputniks in the orbit make it possible to determine their geodetic position in space in relation to the Earth's centre within about 30 to 50 feet.

Given a number of these positions for ten to fifteen regions of the Earth's surface, it is possible to determine the Earth's shape more accurately than ever before.

As a result, we shall be able to refine the continental geodetical system.

These observations will also enable scientists to understand better the distribution of mass in the interior of the Earth.

The sputniks move in the gravitational field of the Earth and this field in turn is determined by the distribution of the masses in the Earth's interior and its crust.

Studying the movement of the sputniks we can highly refine our knowledge of the gravitational field of the Earth and thereby arrive at interesting conclusions about the Earth's structure.

True, revolving around the Earth is also the real Moon, but a study of its motion gives us information only about those parts of the terrestrial gravitational field which are a relatively long way away from Earth.

Of course at over 200,000 miles of distance the terrestrial gravitational field depends much less on the disturbance of mass in the interior of the Earth.

The study of the Moon's motion can therefore furnish only very meagre information on this question.

Artificial satellites, however, launched something like 600 miles above the Earth's surface, offer many more opportunities in this respect.

The Upper Atmosphere

IN STUDYING THE HEAVENLY BODIES around us and the outer space in which the Earth moves, scientists have encountered considerable difficulties due to the fact that the observations and scientific stations are situated at the bottom of an ocean of air surrounding the Earth, an ocean hundreds of miles deep.

This ocean lets through to us only some narrow regions of the spectrum of electromagnetic waves emitted by the Sun, stars and other heavenly bodies.

Scientists have therefore always dreamed of observatories beyond the atmosphere.

Observatories on sputniks would meet the case—opening up new possibilities for carrying out all kinds of scientific experiments that earlier seemed impossible.

By the upper atmosphere today we mean the region above twenty to twenty-five miles high. This region is of great practical interest, as it is the medium through which artificial satellites travel and the routes of future interplanetary ships will pass.

In addition, the upper atmosphere is the medium in which radio waves are propagated.

The strata and regions with high ionisation forming in it reflect

or scatter the waves, thereby creating the conditions for their propagation over great distances.

At the same time, under certain conditions, the upper atmosphere sometimes becomes a medium in which radio waves are absorbed.

The processes going on in the upper region of the atmosphere are characterised by a great many features which are not usually preserved in its lower parts.

Among these are the features related to the continuous chemical conversions of the atmosphere's molecules and atoms and their ionisation which occurs when they are irradiated by the penetrating ultraviolet, X-ray and corpuscular emissions of the Sun.

In the higher parts of the upper atmosphere, the change of its relative atomic composition becomes significant.

Here the lighter molecules and atoms predominate, owing to the force of gravity.

The circulation of this ionised atmosphere, which is an electrical conductor, in the Earth's constant magnetic field is accompanied by the generation of electric currents which cause different kinds of variation in this field.

Aerial Tides

Valuable information on the circulation of the upper atmosphere has been obtained by the observation of the drift of meteoric trails, by means of optical instruments and radar, and by the observation of the tides in the atmosphere caused by the Sun and Moon.

We know of the high and low tides of the seas, yet tides are much more intense in the upper atmosphere.

From the observations approximate characteristics of the upper atmosphere have been derived.

The temperature in the upper part has been estimated to be several thousand degrees and the density about 1,000 million molecules and atoms per cubic centimetre (at an altitude of some 200 miles). This is less than one ten thousand millionth of the air's density at the Earth's surface.

It had been believed that in the upper atmosphere there were three or four distinct ionised strata.

However, the information gained about the penetrating ultra-violet and X-ray radiation of the Sun which is absorbed by atmosphere and does not reach the Earth's surface, was until recently rather hypothetical.

The dynamics of the upper atmosphere related to the photo-chemical

changes and ionisation remained unclear.

Too little is known also about corpuscular emission, which causes the auroras.

Without exact knowledge of these disturbing factors, it is difficult to build up a general theory of the dynamics of the processes going on in the upper atmosphere.

Certain Radiations

Of late there has been considerable development of the study of emissions, that is, certain forms of radiations of the upper atmosphere.

Much valuable data has been obtained in this way.

For instance, by using spectroscopes it has been established that the Earth's atmosphere about sixty miles up is colder over the equator and warmer over the polar regions.

That is a very important factor for the origination of circulation.

The higher temperature in the polar regions leads to a highly original structure of the top regions of the atmosphere, called the exosphere.

The ionised particles in a highly rarefied medium can move only along magnetic lines of force, and therefore projections of ionised particles or columns are formed over heated areas and they are sometimes discovered in the twilight hours when the exosphere is lit.

These are the so-called high radiant structures of polar auroras.

Interesting information about ionisation has been obtained by radar investigations of the auroras.

Meteors greatly influence the properties of the upper atmosphere.

Their fall leads to the formation of readily ionisable oxides of nitrogen and shock sound waves, which cause variations in the density of the medium.

This phenomenon occurs in the upper atmosphere also when sub-audio waves produced by winds and the disturbances of the ocean surface and so on, penetrate up there from the lower atmospheric levels.

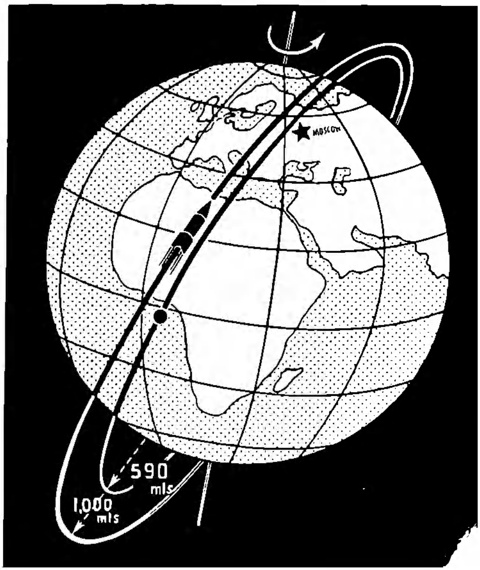
The outer part of the atmosphere is like the agitated foaming of the sea during a storm.

Rocket Investigation

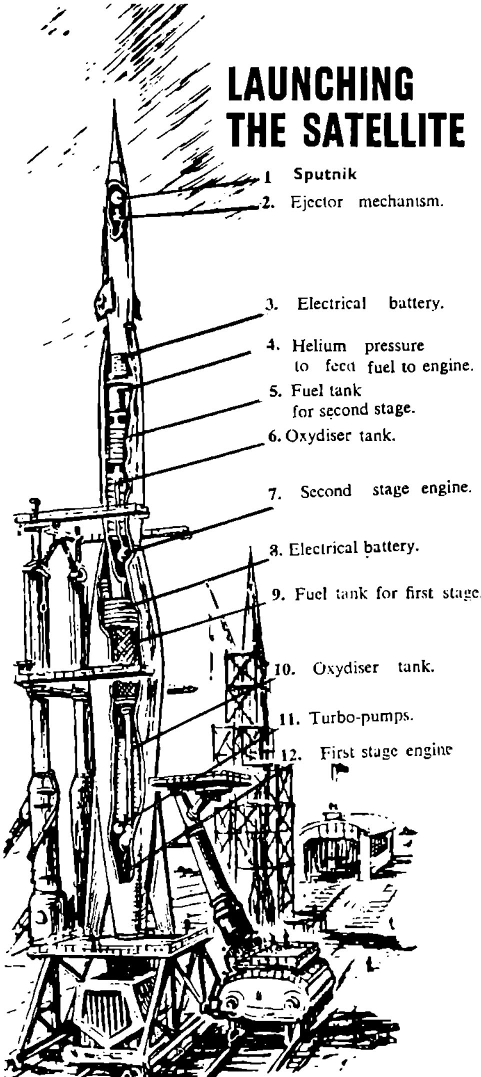
In recent years new and important results have been obtained through the use of rockets in investigations of the upper atmosphere.

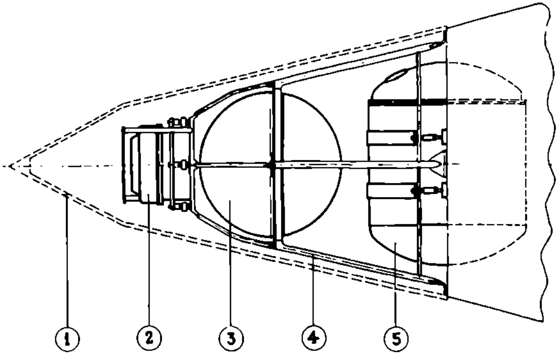
ORBITS: The diagram below shows the rotation of the Earth and the orbits of Sputnik I and Sputnik II.

THREE GENERATIONS: V. Vasilichenko, a Moscow engineer, is a keen "ham". Above, we see him with his family around his transmitter/receiver listening to signals from Sputnik I. Grandmother knew the bad old days before 1917, whilst the future holds untold wonders for her grandchild.

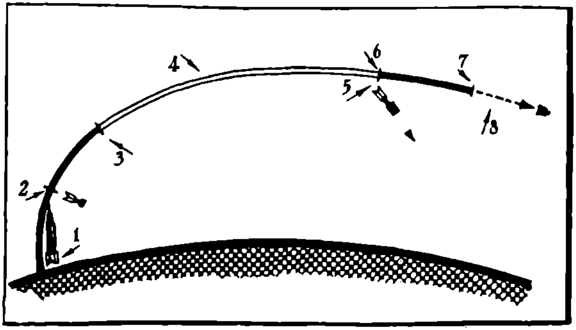


LAUNCHING THE SATELLITE





A diagram of the nose of the rocket carrying Sputnik II. (1) *A protective cone which drops off as the satellite enters its orbit.* (2) *Solar, cosmic and X-ray radiation instruments.* (3) *Radio in sphere.* (4) *Frame carrying apparatus.* (5) *Hermetically sealed cabin for Laika.*

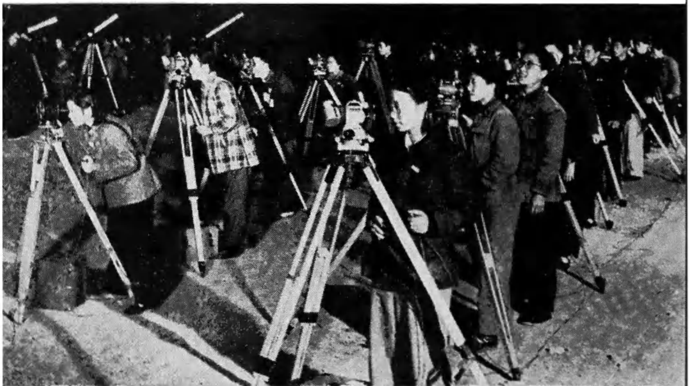


A ROCKET'S TRAJECTORY: This diagram illustrates the stages in the launching of a sputnik by rocket carrier. (1) *Starting point.* (2) *Detachment of Stage One.* (3) *Stoppage of engine in Stage Two.* (4) *Flight by inertia.* (5) *Detachment of Stage Two.* (6) *Stage Three engine comes into operation.* (7) *Detachment of Stage Three.* (8) *Sputnik's orbit.*

The last stage of Sputnik I's rocket carried over into an orbit of its own. Being larger than the satellite it was often visible to the naked eye. The picture above shows its trail. The break indicates the "right overhead" position. Stars appear as lines, having moved during the exposure.

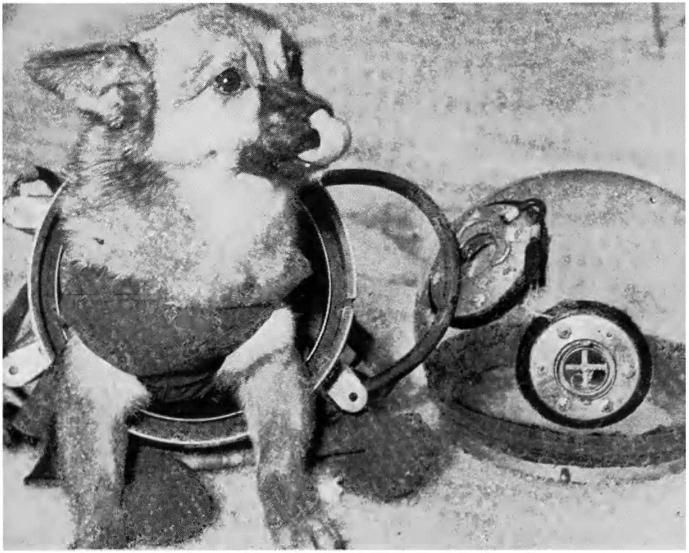
The crowd of Soviet citizens below watch the progress of this latest wonder of the heavens.

Muscovites flock to the Planetarium (below) and listen to lectures on the sputnik. There is widespread interest in Japan, too, and the top picture shows an audience in Tokyo Planetarium as the lecturer shows a model rocket.

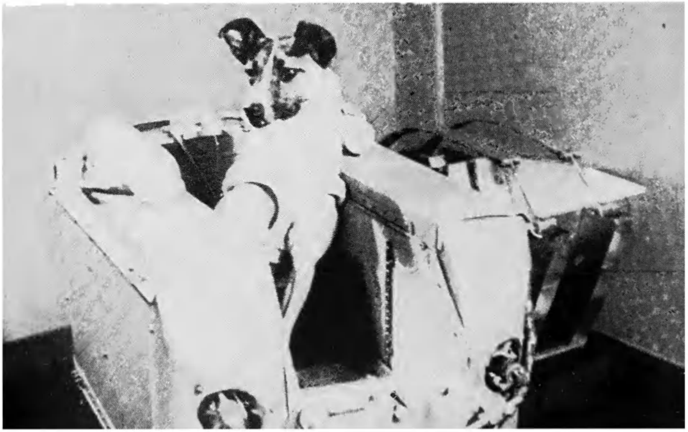


SPUTNIK - WATCHING in California, U.S.A. (top), Peking, China (centre) and Moscow, U.S.S.R.

FOR THE I.G.Y.: The sputniks are part of the programme of the International Geophysical Year researches, and the group above are at Blossom Point, La Plata, checking orbits. Left to right: E. Habib (U.S.A.), C. Castros (Ecuador), A. M. Kasatkin (U.S.S.R.), L. V. Barkner (U.S.A.), H. Khafsar (Iran), A. A. Blagonravov (U.S.S.R.). Below, young Americans tackle Soviet scientists Kasatkin, Blagonravov and Polozkov for autographs after a "Youth Wants To Know" TV programme in Washington.



Two of the dogs which have contributed to our knowledge of space travel. Above is Malyshka, an experienced "astronaut", seen here with its space-suit having just returned from a rocket trip. Below is Laika in her travelling cabin of Sputnik II.



A lower density and lower temperatures have been found above 100-125 miles.

Exceptionally valuable results have been obtained in determining ionisation; it was found that there is a gradual and smooth rise in ionisation with a large number of very shallow peaks, which it is difficult to identify with the sharply defined simple strata assumed earlier.

The real ionosphere proved to be lower than had been believed, and the penetrating ultra-violet and X-radiation of the Sun has been measured directly.

The measuring of absorptions of the penetrating solar radiations has made it possibile to bring out the fact of the lower density of the upper atmosphere.

However, a weakness of rocket investigations has been their momentary nature.

Artificial satellites can ensure long and continuous observations over different localities of the globe, and therein lies their chief advantage.

Most important is observation of the penetrating ultra-violet, X-ray and corpuscular emissions of the Sun.

Investigating the Sun

On Sputnik II instruments for investigating the Sun's radiation were installed.

Three special photoelectronic multipliers set up at an angle of 120 degrees to each other serve as the radiation receivers.

Each multiplier was successively covered with several filters made of thin-metal and organic plates and also by special optical materials, which made it possible to separate different ranges in the X-ray region of the solar spectrum and the hydrogen line in the far ultra-violet region.

The electric signals produced by the photomultiplier trained on the Sun were amplified by radio and telemetered to the Earth.

Owing to the fact that the sputnik has continuously changed its orientation in relation to the Sun and part of the time was lit up by the Sun, to economise on power the electric circuit was switched in only when the Sun appeared within the range of one of the three light receivers.

It was switched in with the aid of photo-resistors lit by the Sun simultaneously with the multipliers and the system of automatic control.

Parallel with observations of solar radiation from the sputnik, observations of the Sun are also conducted by the whole network of the "solar service" ground stations under the I.G.Y. programme.

By comparison of all these observations, it will be possible to arrive at preliminary deductions on what connection there is between the Sun's ultra-violet and X-radiations and the processes going on in the chromosphere and the Sun's corona and the state of the Earth's ionosphere.

All this will serve as a basis for the regular observations to follow.

Cosmic Dust

Outer space is full of cosmic dust, the nature and characteristics of which it has not been possible to study directly.

Science had only conjectures on its origin and characteristics.

With the artificial satellite serving as a laboratory it will be possible to begin direct study of this problem too.

What makes it important is the likelihood that cosmic dust is the material out of which planets are formed.

Since Newton's days scientists all over the world have been pondering over the physical nature of terrestrial gravitation and the force of interaction between material bodies in general.

But it was only Einstein's theory of relativity which lifted the veil slightly from the mystery of these phenomena and hence attracted the attention of the vast majority of scientists throughout the world.

So convincing is Einstein's conception that today it is the only rational theory explaining many cosmic phenomena.

However, in some respects it has to be refined and checked by experiments.

Sputniks launched to move at high altitudes can help to check experimentally some aspects of this theory, one of the fundamental theories of modern science.

It is known that the Metagalaxy possesses a definite luminosity and its value should be in agreement with the general theory of relativity.

It is difficult to measure the luminosity of the Metagalaxy from the Earth's surface because of the night-sky air-glow, but with the aid of a sputnik it will be easier to solve this problem.

When we have measured the luminosity of the Metagalaxy, we shall solve an important cosmic problem and verify certain theses of the general theory of relativity.

Bringing Mars Nearer

Further, in astronomical observations by telescope from the Earth's surface, magnification of 900 times is ordinarily the limit, because of

interference caused by tiny air streams in the atmosphere which break up and blur the images of stars and planets. It is because of these air streams that the stars appear to twinkle.

Beyond the atmosphere, however, magnification as high as 10,000 times is possible, so that objects on the Moon 40 feet across, and objects on Mars about a mile across will be distinguishable.

Of considerable interest is the study of electric fields at heights in the neighbourhood of 600 miles, and the solution of the problem of whether the Earth and its atmosphere constitute a charged or a neutral system.

Along with indirect studies of the ionosphere, by observing the passage through it of radio waves, the programme of investigations by sputnik envisages direct measurements of ionic concentration at different altitudes, and later the chemical composition of the ionosphere by mass spectrometry.

If the present ideas that there are no negative ions at great altitudes are correct, these experiments will furnish complete information on the composition of the ionosphere.

Slowing Down

Of great interest for science is the study of the radiation arising from the disturbance of the atmosphere by a body moving at cosmic speed.

This radiation becomes especially interesting as the sputnik is slowed down and gets into the lower strata—behaving like an enormous artificial meteor which excites and ionises the molecules and atoms of the surrounding medium.

It is particularly valuable if all these observations can be correlated with simultaneous observations from the Earth's surface, under the current I.G.Y. programme.

Of course, to solve all these problems many sputniks will be needed, equipped with all kinds of instruments of a high degree of perfection. And the data thus obtained will, of course, give birth to a great many new problems.

Cosmic Rays

Cosmic rays come to us from outer space. These radiations are a stream of nuclei of the atoms of different elements travelling at velocities very close to the velocity of light.

They are the heralds of gigantic processes elsewhere, as a result of which the nuclei of atoms of elements have been accelerated to very great energies.

Cosmic rays produced in this way offer us the possibility of study-

ing the cosmos at great distances from the Earth, and even from the solar system.

In most cases the energy of the particles of cosmic radiation amounts to thousands of millions and even tens of thousands of millions of electronvolts.

Some of the particles, however, attain energies millions of times greater.

So far particles have been found with an energy of as much as a billion billion electronvolts.

This high energy of cosmic ray particles makes it possible for physicists to use them effectively to "bombard" atomic nuclei, and to study the laws operating only at the extremely high energy of the colliding particles.

The study of cosmic rays, especially with the aid of instruments mounted on a satellite, will make it possible considerably to simplify some of the studies which, when conducted on the ground, require highly powerful accelerators such as a cyclotron or proton synchrotron.

The world's biggest proton synchrotron, in the Soviet Union, can accelerate to an energy of a "mere" 10,000 million electronvolts, and one we are now building will "only" bring it up to 50,000 million electronvolts.

Not many particles of cosmic radiation reach the Earth. On the average a square centimetre receives one particle a second.

In spite of the great energy of the individual particles, the total energy of cosmic radiation is therefore small, being equal approximately to that brought to us by the light from the stars.

Where do they Start?

That is a trifle compared with the energy entering the Earth from the Sun.

However, far away from the Sun the cosmic rays play no small part in the general energy balance.

The question naturally arises—how do cosmic rays come into being? There can be no doubt that as a rule they start far out from the Earth and far even from the solar system.

Sometimes, though extremely rarely, the Sun itself is the source of cosmic rays, and in such cases explosive processes have been observed on the Sun.

Cosmic rays produced on the Sun consist of particles possessing little energy, which shows that the scale of phenomena taking place

on the Sun is very small compared to those which cause the formation of most cosmic rays.

Where, then, in the Universe do these gigantic processes occur?

To answer this question, it is first necessary to study the composition of primary cosmic radiation.

When colliding with the nuclei of the atmosphere's atoms the particles of cosmic radiation impart a portion of their energy, sometimes a very considerable portion, to secondary radiations, and owing to the high energy of the particles of cosmic rays a good many generations of secondary particles appear.

For this reason, what we are studying on the Earth's surface and in the stratosphere, too, is not the primary radiation which came from cosmic space but mostly its innumerable offspring.

Space Laboratories

In order to study primary cosmic rays, scientific apparatus has to be lifted beyond the Earth's atmosphere.

Hitherto we have been able to lift instruments to considerable heights by means of sounding balloons (radiosondes), stratostats or rockets, but in the first two cases primary radiation is masked by a secondary, while in the case of rockets the time of measurement is limited to a few minutes.

Sputniks make it possible to study fully the composition of primary cosmic radiation.

We shall very likely succeed in finding new components of cosmic radiation which will reveal many of the universe's secrets.

Physicists have long tried to establish the age of cosmic rays, to find out how much time has passed since the particles of cosmic radiation obtained their great energy and began their wanderings through the universe.

This question, however difficult it seems to be, can nevertheless be answered if we turn to account the fact that the longer cosmic rays travel in the universe the more often they collide with the atoms in interstellar space.

In such collisions the atomic nuclei of heavier elements in cosmic rays will break up and nuclei of lighter elements will be formed out of their fragments.

In cosmic rays we find nuclei of the atoms of different elements. The more nuclei of the atoms of a particular element there are in the cosmos the more of them will become accelerated and gain high energy.

Experiments have shown that the composition of cosmic rays corresponds, in the main, to the distribution of the different elements in the universe.

Though there is very little of some elements in the cosmos, lithium, beryllium and boron, for instance, yet the nuclei of these elements are often produced when heavier nuclei decay.

Long Journey

Consequently if such nuclei are found in the composition of primary cosmic rays it will mean that the cosmic radiation has travelled a long time in the universe.

To find the nuclei of atoms of different elements in the composition of cosmic rays is a very difficult problem.

It may be successfully solved by using special counters, which register the Vavilov-Cherenkov radiation.*

The greater the specific gravity of the element the more intense the radiation of the atomic nucleus passing through the counter.

As shown by experiments carried on by the Soviet scientists Kurnosova, Razorenov and Fradkin, this is a good way to analyse primary cosmic radiation and especially to try to find out if it contains the nuclei of lithium, beryllium and boron.

In the same way the nuclei of the atoms of many other elements, particularly heavy elements, can be searched for in cosmic rays.

The large opportunities offered by the satellites will permit undertaking new attempts to find among primary radiation electrons, and photons, the tiniest material particles of light.

If these new components were to be found even in very small quantities our knowledge of the origin of cosmic rays would be considerably advanced.

This will be evident, indeed, if we recall that there are magnetic fields in outer space.

While passing through the Earth's magnetic field the cosmic ray particles are greatly deflected in the field, and as a result the primary particles of cosmic radiation, possessing as they do an electrical charge, follow a considerably distorted path.

Observing these particles on the Earth, we cannot tell where they came into being since the original direction of their motion has been completely lost, owing to the deflection in the magnetic fields.

* The "Vavilov-Cherenkov effect" (named after the Soviet scientists who discovered it) is that charged particles fly through matter at a velocity greater than the velocity of light in that medium, producing an original light-wave similar to the sound-wave produced by a plane flying at supersonic speed.

Photons' Messages

Photons, on the contrary, move in practically a straight line. If, therefore, we succeed in finding them they will be better than any other radiation indicating to us where in cosmic space the sources of cosmic rays are to be found.

Thus, study of the composition of primary radiation will make it possible to discover a number of phenomena occurring in cosmic space and to shed light on the origin of cosmic rays, and in particular to check some consequences of V. L. Ginzburg's hypothesis that cosmic rays are formed by supernovae outbursts.

With the aid of sputniks, long observations of primary cosmic radiation can be conducted affording the possibility of discovering even relatively small variations in the intensity of the different components of this radiation.

In every particular case it is very interesting to find out the nature of those particles of cosmic radiation which have changed in number. The use of sputniks will make this possible.

Among other things, the number of primary particles can be registered to this end and simultaneously the ionisation they cause.

In this way it will be possible to separate the variations in the intensity of the main component of cosmic rays consisting of the nuclei of the atoms of hydrogen, namely, protons, from the changes in the number of nuclei of the heavier elements.

Instruments on the Earth's surface cannot effect this separation, but satellites offer an altogether new approach to analysing the processes going on with cosmic rays.

Counting Particles

The number of primary particles can be measured with the aid of a counter of charged particles.

Considerable difficulty is presented in measuring ionisation produced by cosmic radiation beyond the atmosphere.

However, the measurement can be managed by employing a method developed by Chudakov, as follows: owing to the ionisation, the instrument travelling outside the atmosphere accumulates an electric charge, and when the charge is removed an impulse emerges which is radioed to the Earth, and the ionisation produced by the cosmic rays can be judged from the value of the impulse.

The orbits of the sputniks girdled almost the entire globe, and this made it possible to study the dependence of the intensity of cosmic radiation on latitude and longitude.

This dependence is due to the deflection of the primary cosmic rays in the Earth's magnetic field.

By utilising the Earth as a huge measuring instrument the composition of cosmic radiation can be analysed, and the distribution of the radiation over the globe makes it possible to investigate our planet's magnetic field.

Instruments for studying cosmic rays were installed in Sputnik II.

The particles making up cosmic radiation were registered on the sputnik with the aid of charged particle counters.

When an electrically charged particle passed through the counter, a spark was produced which supplied an impulse to the radio circuit incorporating semi-conductor triodes, the purpose of which is to add up a number of cosmic ray particles and signal when a certain number has been counted.

Cosmic Help

After transmitting the signals that the particular number of particles had been totalled, registration of cosmic ray particles began again and when an equal number of particles had been counted another signal followed.

Dividing the registered number of particles by the time in which they were counted, we get the number of particles passing the counter per second, or, in other words the intensity of cosmic rays.

Preliminary analysis of the data on the cosmic rays transmitted from the sputnik has shown that the instruments functioned normally.

It has been definitely shown that the number of particles of cosmic radiation depends on the geomagnetic latitude, and the analysis of the many measurements of the energy spectrum of the primary cosmic particles makes it possible to study the variation of the spectrum with time, and compare it with the processes going on during that time in the space around it.

There can be no doubt that in time instruments mounted in sputniks will provide the possibility for a continuous observation of the primary cosmic radiation.

In this way cosmic rays will become a powerful means of studying the Universe.

Ionosphere's Secrets

There has been very little investigation of the atmosphere above 150 miles or so.

Especially interesting is the study of the structure of the ionosphere, the layer of the atmosphere which contains a vast number of electrically charged particles—electrons and ions.

Science today possesses little information about the circular electrical currents in the ionosphere and other related phenomena, for until now the principal information on the ionosphere has been obtained by studying the paths of the radio waves sent from the Earth and reflected from the ionised strata.

This method, however, makes it possible to get some idea of the ionosphere only up to the level of maximum ionisation (F2 layer), that is, up to a height of roughly 150-200 miles.

This is because the ionosphere reflects or lets through radio signals, depending on their frequency. The higher the frequency the greater the density of ionisation required to reflect the signals.

The highest frequency at which radio waves are reflected from a particular layer of the ionosphere, when they fall vertically on it, is called the critical frequency.

The highest critical frequency is observed in the F2 layer.

Radio waves of a frequency higher than the critical frequency of the F2 layer pass through the ionosphere and do not return to the Earth. In order to study the higher layers of the ionosphere, therefore, we must have radio-wave sources placed considerably higher than the F2 layer. It is such sources that the sputniks carried.

Beyond the Ionosphere

However, radio waves from the sputnik falling on the ionosphere from outside can also be reflected and so never reach Earth. To avoid this, the sputnik's radio transmitters had frequencies higher than the critical frequency of the F2 layer, with a range of 10-15 megacycles, depending on the season of the year.

> **Radio waves emitted from the sputniks made it possible to get signals from an area in the ionosphere in which radio waves from the Earth cannot penetrate.**

Radio observations were conducted from widely varied positions by radio direction-finder stations, radio clubs and thousands of amateurs.

Of very great importance are measurements of the field intensity of radio signals received from sputniks.

These measurements have been made by continuous automatic recording as well as by separate measurements at certain fixed instants,

and so much material has been obtained that so far only a preliminary analysis has been completed.

The signals transmitted on the 15-metre wavelength were audible far beyond the direct vision range.

While in the southern hemisphere the sputniks travelled above the ionosphere; in the northern hemisphere at certain moments it was above the peak ionisation of that stratum, at other moments under it, and at still others, near the peak.

These conditions make for a great many ways of propagation of short waves over great distances.

One of these ways is the reflection from the Earth's surface of the radio waves which have come from above through the whole mass of the ionosphere, followed by a single reflection of it from the ionosphere in the regions where the critical frequencies are sufficiently high.

In other cases the radio waves falling on the ionosphere from above at a certain angle are considerably refracted by it and as a result penetrate into a region lying beyond geometrical direct visibility.

Favourable Conditions

The position of the sputnik near the area of maximum ionisation of the atmosphere creates especially favourable conditions for the propagation of radio waves by means of ionospheric wave-guides.

In some cases, as the observations have shown, radio waves came to the receiving point not by the shortest route but rather travelled about the globe over the longer arc of the great circle.

In some cases the phenomenon of round-the-globe echo of the radio signals has been observed.

There can be no doubt that the final analysis of the great amount of material obtained through radio observations of the sputniks will provide very valuable information on the specific features of ionisation of the upper layers of the ionosphere and the absorption and propagation in them of radio-waves.

Earth's Magnetism

There is a natural magnetic field around the Earth. Its properties—for instance, its directional effect on the magnetic needle—have long been utilised in practice, though the nature of the field and its origin still remain obscure.

The Earth's magnetic field affects the motion of charged particles coming from the Sun to the Earth through outer space, particles

formed in the upper layers of the atmosphere when these layers are ionised by the Sun's ultra-violet rays.

This is the explanation for geomagnetic effects such as the way the intensity of cosmic rays varies according to latitude, and the frequency of auroral displays, the polarisation of radio waves reflected from the ionosphere and many other things.

Until recently the Earth's magnetic field was measured either on the Earth's surface or close to it (from aeroplanes). It is only recently that a few measurements have been taken from rockets at altitudes exceeding sixty miles.

The mathematical analysis of the measurements made on the ground has led to a number of interesting deductions.

It turned out that the field observed near the Earth's surface should be regarded as consisting of two parts: one due to sources in the interior of the Earth, and the other to sources outside the Earth.

Although the share of the outer sources is very small (1 to 3 per cent), its value lying close to the limits of the error involved in the mathematical analysis, there is no doubt that it really exists.

The existence of an external field is confirmed by the rapid changes taking place in the Earth's magnetic field, changes that are known as diurnal magnetic variations, magnetic disturbances and magnetic storms.

These changes are closely related to many phenomena occurring outside the Earth's surface, such as solar activity, the state of the ionosphere, auroral displays and cosmic rays .

Outside the Earth

A mathematical analysis of the changes shows that their sources lie outside the Earth's surface.

Unfortunately, the analysis of the data obtained from ground observations will neither indicate the exact spot where the field's sources are to be found nor define their nature.

Other data have to be found for this purpose.

Investigation of the daily variations, magnetic storms and the phenomena related to them have led scientists to assume that an external magnetic field may be produced by systems of electrical currents outside the Earth's surface.

The most likely place where such currents might originate is in the upper conductive layers of the Earth's atmosphere, namely, the ionosphere.

It is also suggested that there may be currents beyond the ionosphere too.

They may possibly be due to charged particles and corpuscles, ejected by the Sun and captured by the Earth's magnetic field and revolving around the Earth in the plane of its magnetic equator tens of thousands of miles away from the Earth.

These extra-ionospheric currents increase when, during magnetic storms, the Earth finds itself in the midst of intensive corpuscular streams ejected from the Sun's active regions.

At such times their magnetic field shifts the zones of auroral displays closer to the equator and reduces the intensity of cosmic rays.

The presence of sources of a magnetic field in the ionosphere is confirmed today by direct magnetic measurements conducted from rockets.

Considerable attention is being given in the International Geophysical Year to studying the varying external magnetic field and its relation to solar and other geophysical phenomena.

The changes in the magnetic field are being registered continuously at a great many stations.

It is also planned to measure the magnetic field from satellites and rockets, to check the existence of extra-ionospheric currents, to find out the system of ionospheric currents and learn more about the main part of the field, i.e. the part of it due to the Earth's interior sources.

Sputniks can check whether the streams of the Sun's particles are neutral or consist of positive or negative electrically-charged particles.

Data on the part of the field created by external sources can be obtained by comparing the measured values of the field with the theoretical calculations based on the assumption that the field is produced only by sources in the interior of the Earth.

Knowing the field produced by the external sources at high altitudes, it will be possible to appraise better the part it plays in particular geomagnetic effects.

It is not impossible, incidentally, that in some cases it plays a considerable part.

In particular, the recently revealed difference in the position of the Earth's geomagnetic equator as found from the data obtained by magnetic measurements on land and by measurements of the intensity of cosmic rays, may possibly be caused by the action of the field's external sources on the charged particles of cosmic rays.

Observing that the intensity of the large magnetic anomalies decreases with altitude, we shall be able to judge whether the sources of these anomalies lie near the Earth's surface or far out in space.

Weather Forecasting

It is close to seventy-five years since the first attempt was made to carry out geophysical investigations simultaneously on a world-wide scale.

That was the first international polar year. Its task was to study the influence of the Arctic on the weather, and to investigate the Aurora Borealis and the Earth's magnetic field.

The second attempt was made fifty years later, in 1932-33, when the second international polar year was organised.

The object of that attempt was to study the ionosphere and its effect on the propagation of radio waves, and to conduct meteorological observations by an extended network of stations.

The meteorological maps compiled following the observations of the second international polar year (for the Earth's northern hemisphere) served scientists as a basis for developing a thermo-hydrodynamic method of long-range weather forecasting, and to verify whether the experimental hydro-dynamic long-range forecasts were justified.

The next international meteorological observations were planned for 1982-83, but the rapid rate of development of science and technology in the middle of the twentieth century made it necessary to change the schedule and fix the I.G.Y. for 1957-58.

Sixty-four countries are participating in the I.G.Y. The U.S.S.R. is taking an important part in carrying out its programme.

Some 300 meteorological ground stations and some 100 aerological stations have been set up on Soviet territory.

The work done under the I.G.Y. programme will be extremely important for meteorology, especially for weather forecasting, which is the principal problem in this science.

For the first time the results of observations by a wide network of meteorological stations will be received from both hemispheres of the Earth.

First Time

This will be the first time that meteorological conditions in the Antarctic and equatorial regions will have been widely analysed, an analysis that meteorologists need so very badly.

Vast quantities of material will be collected for meteorology during the year, and electronic computers will analyse the material very quickly.

Calculations, which formerly would have taken scores of years, can now be done in a few hours.

Automatic meteorological stations set up on sputniks operating beyond the Earth's atmosphere will, before very long now, lead to fundamental changes in the theory and practice of weather forecasting.

Many meteorological phenomena hidden from observers on Earth will become obvious when observed from the sputnik.

Today meteorologists are forced to collect most of their data from an extremely limited number of ground observations.

However, making use of a satellite it will be possible, for instance, to photograph at once all the clouds over the Earth's surface at least several times every twenty-four hours.

It will also be possible to obtain data on ice conditions and information on other factors influencing the weather all over the world.

Many problems of meteorology are already in the process of solution as a result of the observations of the first two satellites.

For instance, we are now learning the distribution of the density of the air in the upper layers of the atmosphere along longitude and latitude etc.

Future sputniks will help to solve a vast number of other meteorological questions.

Cloud Distribution

By equipping sputniks with special sensitive photo-cells, scientists will get a picture of the distribution of clouds over extensive regions of the Earth's surface and will simultaneously get a picture of the distribution of the gigantic planetary and atmospheric waves (more than 600 miles long), which play a part in shaping the weather over large distances.

Scientists will be able to watch jet currents, that is, a pronounced belt winding among the cyclones and anti-cyclones which block it, like a river winding between islands, and many other things.

The sputniks will furnish a picture of the distribution of the air currents, a picture of total air circulation over wide expanses.

It has been proved that for short-range forecasts (24 to 48 hours) it is necessary to know the initial field of meteorological elements for a relatively small area, surrounding the particular region for which the forecast is made.

However, as the time for which the forecast is made grows longer

the territory which must be covered by the initial information increases sharply.

In the case of long-range forecasts for some point in the northern hemisphere, the initial data may have to cover the entire northern hemisphere as a minimum.

A dense network of stations to take observations, and complete information from these stations, are essential for making more accurate forecasts.

There are still, however, large areas on the Earth's surface in which there are few stations or none at all.

Thus, while on the Atlantic Ocean daily observations are conducted from a few stationary vessels belonging to the meteorological and aerological services, practically no observations are conducted on the Pacific Ocean.

Here observations from sputniks will render indispensable service.

They will cover vast areas including the oceans, on which no regular observations of the state of the atmosphere have been conducted.

Towards Outer Space

SOVIET SCIENTISTS BEGAN THE CONQUEST OF SPACE by conducting a wide programme of medical and biological investigations of animals on their flights in rockets 60-125 miles above the Earth's surface.

From the biological standpoint, a flight in the upper layers of the Earth's atmosphere has much in common with a flight into outer space.

A living organism in that case too, will be affected by a whole series of factors not found in its usual environment, such as the effect of cosmic radiation, existence for a long time in a state without gravity, and, under certain conditions, the virtual absence of atmospheric pressure or molecular oxygen.

Some of these factors can be produced artificially and studied in laboratories, and others during brief flights in rockets.

A good many papers have dealt with the study of their effects on living beings.

Medicine today has enough experimental and theoretical information to reveal more than the merely physiological effects of the influence of these kind of factors.

At its disposal are preventive and protective measures to safeguard the living being—for instance, hermetically-sealed, pressurised cabins, space-suits and so on.

The effects of weightlessness, of primary cosmic radiation, and the corpuscular and ultra-violet radiation of the Sun have as yet practically not been studied from the medico-biological angle.

Their biological effects and perhaps also other factors about which we still have to learn, can be found out only by long flights in the upper layers of the atmosphere.

To conduct such investigations, considerable difficulties as regards design and method have to be overcome.

All apparatus in such cases must operate independently over a long period, ensure automatic recording of the data required and be highly resistant to the action of overstrain, vibrations and variations in pressure and temperature.

At the same time the apparatus has to be compact, weigh little and consume little electricity.

Living Conditions

No less are the difficulties arising in providing conditions to enable animals to survive during the flight.

For instance, the efficient systems of air regeneration used ordinarily are unsuitable for the hermetically-sealed chambers because of their bulk and weight.

New and more efficient systems had to be designed. Obviously the ventilation system had to be a forced-feed system since the gravity-free state precludes the air exchange usual for conditions on Earth.

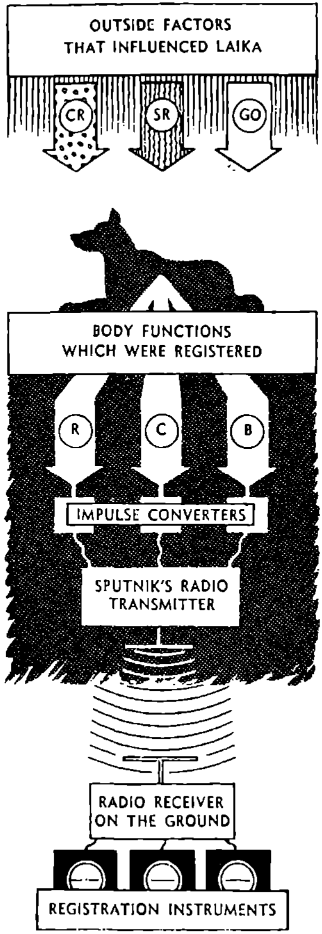
Because of this, the heat exchange in the chamber and protection of the animal from the considerable variations in the temperature have to be specially designed.

A special system had to be worked out to provide the animal with water or liquid food, as in conditions of weightlessness liquids in a free state would probably disperse themselves throughout the chamber, instead of remaining in their containers.

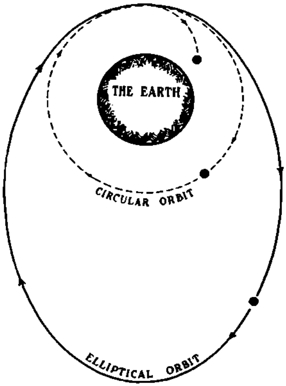
It was necessary to work out a whole system of complex automatic equipment to ensure that the conditions required to keep the animal alive were maintained.

Scientific instruments are used which are designed to investigate a number of basic physiological functions of the animal and hygienic conditions in the chamber (temperature, air pressure etc.).

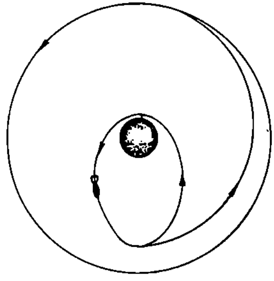
For this purpose, particular physical values are converted into electrical values. Then they are coded into different kinds of radio



MEDICAL AND BIOLOGICAL DATA SENT BY SPUTNIK II: A diagramatic representation of the kind of knowledge gained from the sending of a living organism into outer space. Key to Symbols: CR—Cosmic rays. SR—Solar radiation (ultra-violet and X-rays). GO—Gravity zero (weightlessness). R — Respiration. C — Cardiac activity. B— Blood pressure.

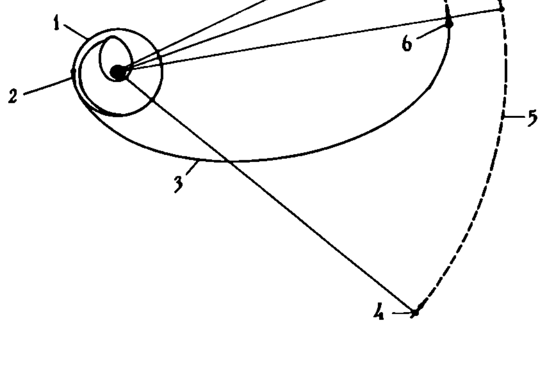


A circular and an elliptical orbit.



The trajectory of a rocket taken out to a stationary orbit, from which it would be possible to proceed to the Moon after refuelling.

The trajectory of a rocket taking off from a stationary orbit to the Moon: (1) Stationary orbit (refuelled here). (2) Position of Earth-controlled rocket at point of departure to Moon. (3) Elliptical trajectory (Earth-controlled) to Moon. Duration of flight 4 days 12 hours 20 seconds. (4) Position of Moon when rocket leaves stationary orbit. (5) Motion of the Moon. (6) Point in space where rocket enters sphere of Moon's attraction. (7) Path of rocket in sphere of Moon's attraction (duration 48 hours). (8) Landing on Moon.



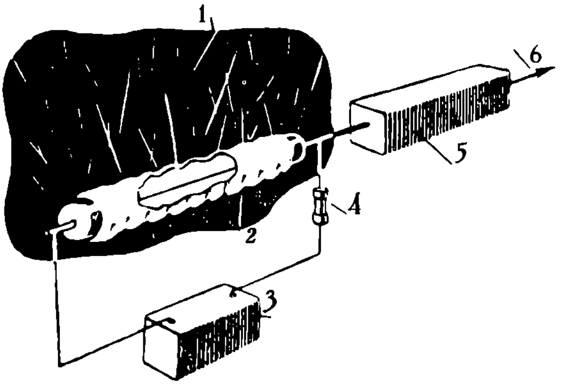
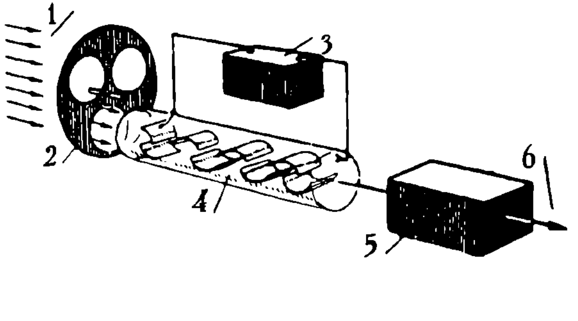


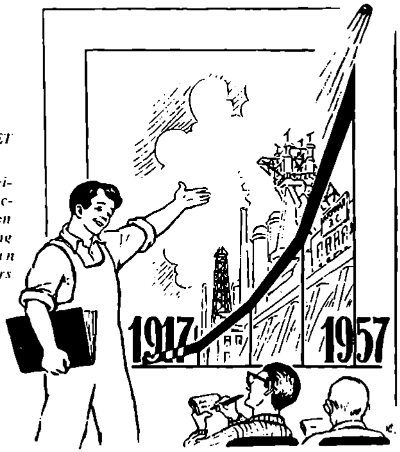
Diagram of arrangement of instrument in Sputnik II to investigate cosmic rays: (1) Cosmic rays. (2) Counter. (3) Storage battery. (4) Resistance (5) Re-computing circuit. (6) To telemetric apparatus.

The arrangement of the solar radiation instrument in Sputnik II: (1) Solar radiation. (2) Disc with alternating filters. (3) Storage battery. (4) Photo-electronic multiplier. (5) Radio-wiring diagram. (6) To telemetric apparatus.



SPUTNIKS IN SOVIET CARTOONS

"To what do you attribute your scientific success," asks the press on the right. And the young Soviet technician answers, "To forty years of Socialism".



On the left we have the heartfelt comment of a motorist: "That's something like *transport– a million miles, and no petrol, no tyres, no maintenance!"*

impulses, which are transmitted by radio and automatically recorded on Earth with the aid of special recording devices.

Even this—by far from complete—enumeration of the problems is enough to give an idea of the variety and complexity of the tasks due to the specific conditions of the experiment.

Observations of Laika's behaviour on Sputnik II made it possible to find out the effect on the organism of factors which could not be studied in laboratory conditions or in high flights in aeroplanes.

Cosmic Biology

In designing Laika's equipment, account was taken of the need of the utmost economy in the size and weight of the instruments and of minimum consumption of electricity by them.

Functioning for some considerable time, the apparatus ensured with the aid of the radio telemetering system the registration of the animal's pulse and respiration, its arterial blood pressure, the bio-electrical potentials of the heart, the temperature and air pressure in the chamber, and so on.

The first "passenger" to tour space on a sputnik was a warm-blooded animal—a dog—the normal physiology of which had been thoroughly studied.

It may be that, to clear up special questions, it will be necessary on later satellites to use anthropoid apes, rodents, molluscs and insects. Insects will afford opportunities for genetic studies.

Laika, the passenger on Sputnik II, was a small dog weighing a little over 12 lb. Unfortunately, her genealogy is not known.

Laika was a phlegmatic animal; while living in the animal house she never quarrelled with her four-footed neighbours. The information obtained from the sputnik shows that during the space flight she did not lose her calm disposition.

Before sending her on the sputnik, Laika underwent preliminary training.

She was gradually accustomed to long stays in a small hermetically-sealed room, wearing a special outfit, and to the gauges attached to different parts of her body for registering the physiological functions, and so on.

The dog was also trained to stand the effect of overstrains, and in the laboratory it was determined how far she was proof against the effect of vibration and certain other factors.

Following long training, the animal calmly endured several weeks

in a hermetically-sealed chamber, which made it possible to conduct the needed scientific investigations.

Preliminary Investigation

The study of the biological phenomena of a living organism travelling in outer space became possible as a result of extensive preliminary investigations on animals in short flights in rockets, to altitudes of 60 to 125 miles, investigations conducted in the U.S.S.R. over a number of years.

This is the story of one such flight.

. . . Five minutes before sunrise a cigar-shaped silver grey rocket was zooming up to the stratosphere.

In the forward part was fixed a non-hermetically sealed compartment in which trolleys had been placed.

Attached to the trolleys were special outfits—oxygen supply instruments, containing 900 litres of oxygen, a parachuting system and apparatus for recording physical functions in flight.

Each trolley weighed about 160 lb., and the parachute system ensured a vertical landing speed of about 20 ft. a second.

The rocket quickly reached a height of seventy miles, at which point the nose—containing the trolleys and their passengers—fell away from the body and began its free fall. When it had dropped to between fifty and fifty-five miles the first trolley was catapulted out at a speed of nearly half-a-mile a second.

Three seconds later, its parachute system began to work and the animal passenger dropped down to Earth from a height of forty-five to fifty miles, the descent taking an hour.

In the last five years Soviet scientists have carried out many similar rocket flights for the purpose of studying the high layers of the atmosphere and their effect on living organisms.

Unlike earlier investigations, the flight of an animal on the sputnik makes it possible to study the effect of zero gravity over a long period.

Before this the influence of weightlessness could be studied only on an aeroplane for a few seconds at a time, and during the vertical launching of a rocket for a few minutes.

On the sputnik, however, it was possible to study the animal's organism in gravity-free state for several days.

The experimental data obtained in the medico-biological investigations are now being studied thoroughly and in detail.

It may be said now, however, that the animal stood up well to the long action of the accelerations as the sputnik was taken to its

orbit and the gravity-free state which followed for several days.

The data show that throughout the experiment the animal's state was satisfactory.

Life on a Satellite

Animals and human beings can travel in outer space only in hermetically-sealed chambers where the air composition and pressure are close to those prevailing on Earth.

In order that its passengers may breathe, a space-ship must have a supply of oxygen, and the most convenient form is liquid oxygen. One gallon of liquid oxygen yields 800 gallons of oxygen gas as it evaporates.

However, the required amount of oxygen dissolves in the blood only within certain barometric pressures. If there is not enough pressure, even if you are breathing pure oxygen, you will not get all you need.

If the barometric pressure drops—in outer space there is practically none—the gases dissolved in the blood "boil" off.

Liquid boiling points depend on the surrounding pressure; the lower the pressure, the lower the temperature at which a liquid begins to boil.

At a pressure of 47 mm. of mercury (which corresponds to about twelve miles above sea level), blood would boil at normal body temperature!

When could such disorders arise? They could occur if something unforeseen happened to the pressurised cabin.

If a meteorite travelling at a terrific speed collided with a space-ship and pierced the chamber, and the astronaut was not wearing protective clothing, he would collapse in fifteen to thirty seconds.

For this reason, in addition to the pressurised chamber, space or special high-altitude suits must be provided.

In space suits the required barometric pressure is maintained, while in the special altitude suits the pressure is produced by tensioning the fabric of the suit, which tightly fits the human body. Both hermetically-sealed chambers and space or altitude suits can be used.

Flights of animals in satellites will make it possible to check the reliability of the cabins and suits, and to work out ways of enabling the organisms to take food and water under these conditions, as well as solving a number of other questions.

An important requisite for the normal life of living beings is an adequate temperature in the surrounding medium. The first experi-

ment of launching a satellite with a dog on board has shown that Soviet scientists have solved the problem of producing the required temperature inside the satellite.

Death Rays from the Sun

It is extremely important to study, with the aid of satellites, the effect of the different kinds of solar and cosmic radiation on living organisms.

The intensity of the ultra-violet radiation in the upper atmosphere and beyond is so great that it is fatal to living cells.

However, protection against the action of the Sun's ultra-violet rays is no difficult problem, since most materials, including ordinary glass, keep out this part of the solar spectrum.

But solar radiation also contains X-rays.

While at first their influence on the organism is quite unnoticeable, it may later lead to very unpleasant consequences. Effective protection against X-rays is essential.

Cosmic rays, or cosmic particles as they should more properly be called, may be even more dangerous.

Possessing enormous kinetic energy, these particles, on encountering molecules of other substances, cause their disintegration into ions.

Molecules become ionised also when cosmic particles penetrate into the tissue of the organism; that leads to the destruction of the cells, to unhealthy symptoms like those caused by gamma radiation, which occurs in nuclear reactions.

The question naturally arises: how can the organism be protected against cosmic particles?

While there are no finished plans on this score as yet, published data indicate that such protection is very difficult.

The launching of sputniks carrying animals will make it possible to obtain highly important information on this question.

Sputnik II was equipped with measuring instruments for studying all "radiant" effects of outer space: the Sun's short-wave ultra-violet and X-ray radiation, and cosmic rays.

Meteorite Dangers

A few words should be said about the danger from meteorites.

More than 8,000 million meteorites enter the planet's atmosphere every twenty-four hours, their total mass being approximately a ton.

Possessing an immense speed—twenty to thirty miles or more a second—they become white hot from friction in the air and burn away in the upper strata of the atmosphere; we see them as "shooting stars".

Meteorites do not, as a rule, penetrate below the 40 to 60 mile levels of the atmosphere.

However, the higher a satellite moves the more likely it is to meet a meteorite.

It is important to establish how much this possibility depends on the height of the orbit, the time of the year, and so on.

In its more than three months in outer space, the first sputnik, we know, did not encounter a single meteorite of destructive force.

It may well be that the chance of colliding with meteoric particles will turn out to be no greater than the chance of a motor accident.

That, however, you may consider bad enough!

Affects of Acceleration

For a satellite to reach its orbit it must undergo a considerable acceleration over a long period.

The effect of this acceleration depends on its magnitude, how long it lasts, how fast it increases, and the direction of the motion in which the force producing the acceleration acts on the body.

The effect of the accelerations, or overstresses as they are also called, on animals and human beings has been studied quite intensively in recent years, since modern high-speed planes are subject to considerable accelerations over long periods.

If the acceleration acts upward from a person's feet to his head it will cause a redistribution of the whole mass of the blood.

There will be more blood than usual in the lower part of his body and not enough in the upper.

If the acceleration is strong enough the blood circulation in the brain may drop below normal, and this will lead to a disturbance in the functions of the central nervous system, including loss of consciousness.

If the acceleration does not act on a person *along* his body but *at right-angles* to it, it can be withstood much more easily.

The special suits also help to protect from overstresses, as they envelop the different parts of the body tightly, not letting the blood accumulate in them.

These questions too will be checked in the experiments with animals.

A few words on the speed of movement the organism can stand.

Uniform speed does not affect the organism.

We certainly are not troubled in the least by the Earth's rotation on its axis. Neither are we disturbed by the Earth's motion around the Sun, at a velocity of more than 60,000 m.p.h.

We may state definitely that the human organism can safely stand any uniform speed.

However, at a certain speed there comes a point when man's senses cannot supply the brain with exhaustive information because the information is transient and incomplete.

Space flights will therefore be controlled chiefly from land stations by means of electronic computing machines with a stored programme. Astronauts in space flights will be released from having to control their flight themselves, which is literally beyond man's capacity.

What is Weightlessness?

Let us now pass on to the question of weightlessness, which space travellers are bound to come up against.

The effect of weightlessness has been studied in recent years on both animals and human beings.

True, the observations were of effects lasting only seconds. Undoubtedly the effects of being a considerable time in a gravity-free state will be quite different.

That is just what satellites carrying animals should establish.

Dogs clad in special space-suits on their brief flights in rockets have also experienced a state of weightlessness.

Automatic instruments recorded the animal's respiration, measured the blood pressure and pulse, and an automatic motion-picture camera took photographs.

No material changes in respiration or heart activity were found. However, such experiments were very limited in time.

Interesting results have been obtained in studying the effect of zero gravity on human beings.

Weightlessness occurs in a specially programmed flight by aeroplane and it continues for 30 to 45 seconds.

Of sixteen persons who have taken part in such flights, eight said that they had felt well. The scientist who conducted the study and who has taken part in a flight, stated that the zero-gravity state was the best form of relaxation for a human being.

Five of the fliers, however, experienced illusory sensations during

the gravity-free state: they had the feeling that they were falling, or that they were flying "upside down".

And one showed symptoms very much like air sickness.

It has been established that, after repeatedly experiencing weightlessness in flight, the human organism adjusts itself to it, and a person who has experienced it several times retains a sufficiently good orientation in space and is capable of making precise, co-ordinated movements.

Without Gravity

The dog's flight on the sputnik, in which the gravity-free state continued for a considerable time, made it possible to study the effect of prolonged weightlessness on the organism and to decide to what extent centrifugal forces should be set up on a satellite to take the place of gravity.

There can be no doubt that weightlessness also affects the organism's functions of breathing, blood circulation, body temperature, and so on. Observations have shown that weightlessness causes some drop in blood pressure.

Under the action of accelerations there is increased gas exchange in the organism, and the consumption of oxygen and production of carbonic acid gas rises several times over.

During the gravity-free state, a drop in the gas exchange may be expected, at least after the organism has become adjusted to this state.

These facts are important for ensuring a supply of oxygen for the animals and for determining the capacity of the air-conditioning apparatus.

Another important reason why satellites have to be launched with animals on board, is the saving of crews of future space-ships.

It may happen that unforeseen circumstances will force pilots to abandon their cosmic vessel, and provision should be made to save the people in such cases.

Naturally, such experiments should first be conducted with animals.

Biological Limits

The height of the orbit above the Earth is important for flights of satellites; the greater the altitude the longer will the satellite survive.

But what about satellites carrying animals? Is there any reason to limit the distance of its orbit from the Earth?

There appears to be no difference, for animals have the same chance for survival at any of the heights to which a satellite can be launched.

The thing is that already at very low heights our atmosphere begins to lose rapidly those of its properties which are essential for a living organism.

At five or six miles above sea level the effect of insufficient barometric pressure is felt, and at about 12 miles, as we have said, blood would boil.

From about 22 to 23 miles up lies the boundary where heavy particles of cosmic radiation are absorbed; above that level in the atmosphere one must be protected against cosmic particles.

Above 26 to 27 miles begins the region which, as regards the ultraviolet part of the solar spectrum, is equivalent to interplanetary space.

Meteorites generally burn away at an altitude of about 60 miles.

At about 76 miles above the Earth's surface and higher, sound cannot travel in the rarefied atmosphere.

At that altitude the distances between the air's molecules are approximately equal to the lengths of sound waves we can hear.

At about the same heights the intensity of cosmic particles begins to increase sharply.

However, the region in which a satellite can survive for a long time is considerably higher than these outside limits.

Man in Space

WE MAY ALREADY SAY that in a very few years sputniks will be built to revolve around the Earth several thousand miles up, and they will be equipped with apparatus for every kind of scientific measurement.

One of the next steps should be the development of a rocket capable of breaking away from the sphere of the Earth's attraction, get close to the Moon and fly around it.

Such a rocket would give us abundant information on the nature of the Moon's surface and on the structure of the other side of the Moon which we never see.

We can say that a flight to the Moon is a matter of the near future.

The carrier rocket of the world's first sputniks gave them an orbital speed of some five miles a second. A space-ship to the Moon would need a speed of only two miles more, or about seven miles a second.

With that speed the space ship would travel in a long ellipse, and entering the sphere of the Moon's attraction, would land on its surface.

The whole trip would take no more than five days, and a minimum of fuel would be consumed.

A route has been calculated by which the flight could be made even more quickly.

If the space-ship flies faster than seven miles a second, it will be able to reach the Moon in twenty-four hours.

Soviet scientists are also working on projects for flights to Mars.

One of these projects envisages the assembly of ten space-ships, each weighing 1,700 tons, on space stations.

From their circular orbit around the Earth they would get out, via a transit orbit, to an ellipse and would move towards Mars in the sphere of the Sun's attraction without using fuel.

The trip to Mars would take 256 days.

For the return flight the travellers will have to wait on Mars—or on sputniks put into orbit round it—for 440 earth days, until the relative positions of Mars and Earth favours the start of the return flight.

The whole trip will thus take 952 days, or nearly three years.

Scientists believe that such flights will be made towards the end of the present century.

There are also projects under which a quicker trip to Mars has been figured out.

At first, space-ships will make their flights without people on board.

The development of cybernetics makes it possible to build equipment which, besides taking measurements, will, without human intervention, also be able to calculate exactly which measurements should be taken and how they should be arranged, in the light of earlier findings.

The radio makes it possible to transmit to the Earth the results obtained in the vast number of observations and measurements very quickly.

Theoretically it is possible also to transmit pictures visible from the ship.

It will thus be possible to obtain enough scientific data without sending people out into outer space.

Considerable technical difficulties have still to be overcome before man is able to fly in outer space. However, the progress made and the continued hard work by scientists give us grounds to believe that before very long man's flight into outer space will become a fact.

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